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(56) Documents Cited:
EP 0032250 A1 **CN 203225053 U**
US 4152847 A1 **US 4095454 A1**
US 2326194 A1

(58) Field of Search:
INT CL **G09B**
Other: **EPODOC, WPI, internet**

(54) Title of the Invention: **An educational and research apparatus for simulating thermal performance and energy efficiency of buildings**
Abstract Title: **Model building for demonstrating thermal efficiency**

(57) **Apparatus intended as a teaching aid for studying the thermal efficiency of buildings comprising a scale model of a building or buildings with sensors that monitor the internal and external environments of the model building. The model's temperature may be monitored by way or infrared thermography. Insulating layers can be added and removed to walls, roof, windows and doors in a modular, interchangeable manner. The thermal environment can be controlled by way of heating or air-conditioning systems and wind circulation and solar radiation can be simulated. The heating and cooling can be computer controlled. The model may be housed in a chamber that may have a removable cover or a handle for transportation**

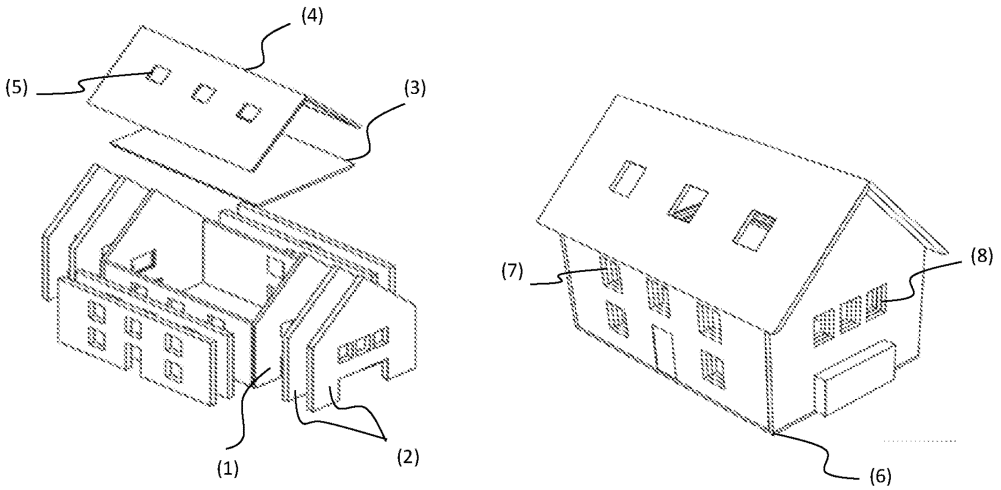

Figure 1

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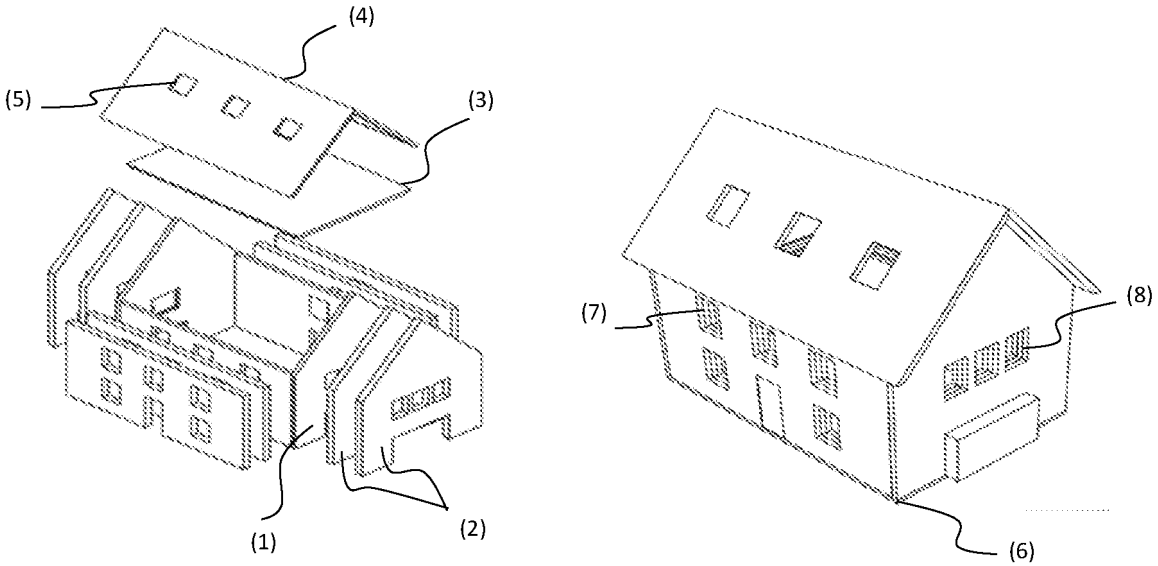

Figure 1

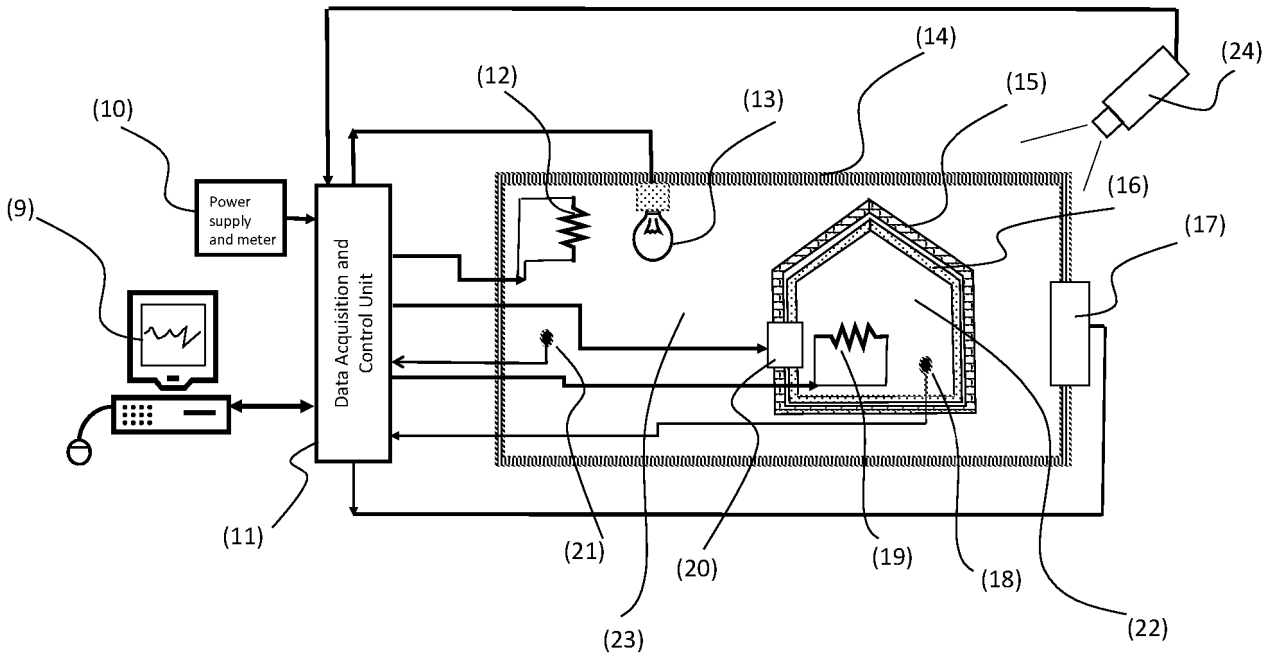

Figure 2

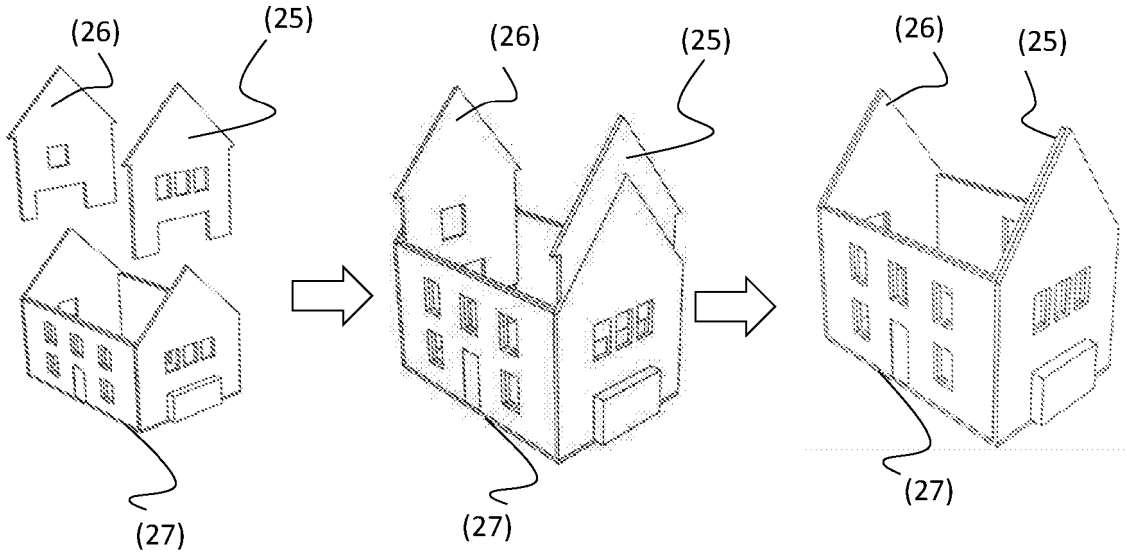

Figure 3

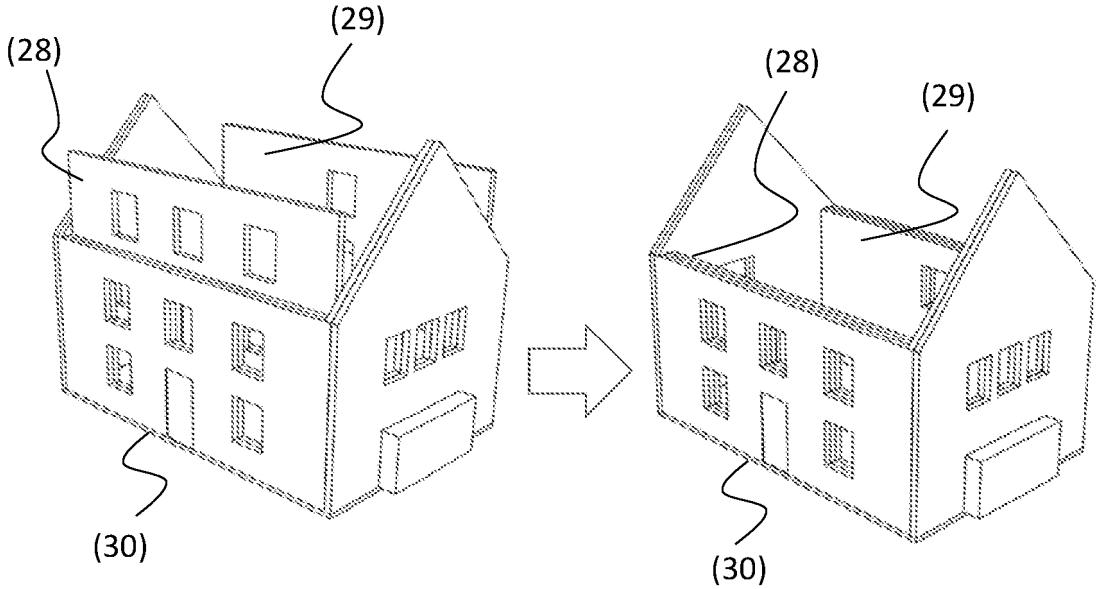

Figure 4

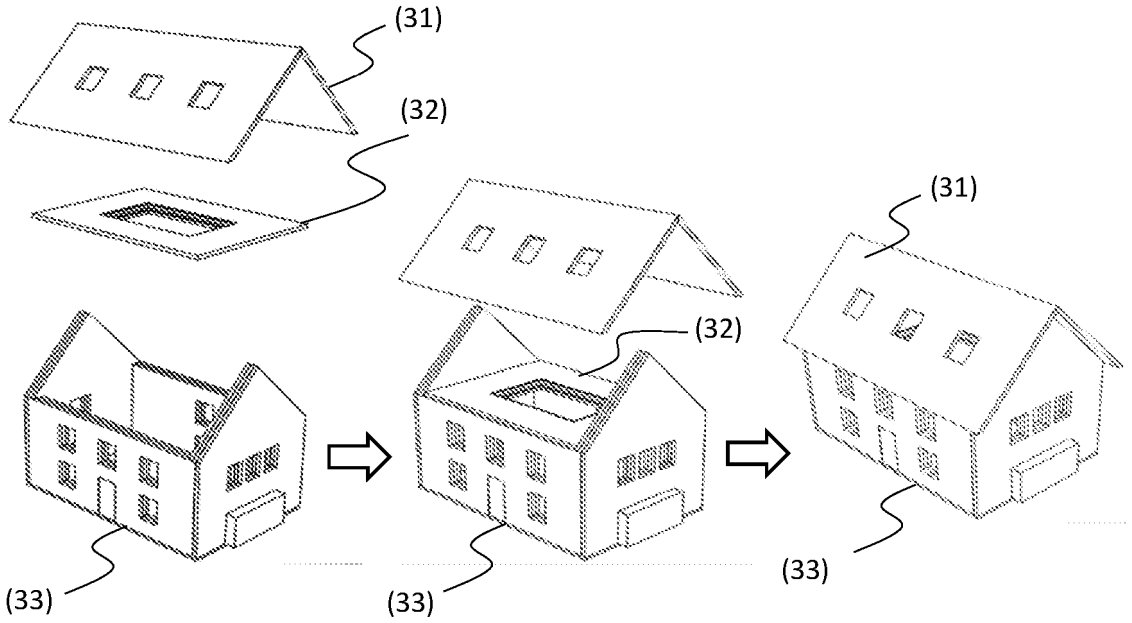

Figure 5

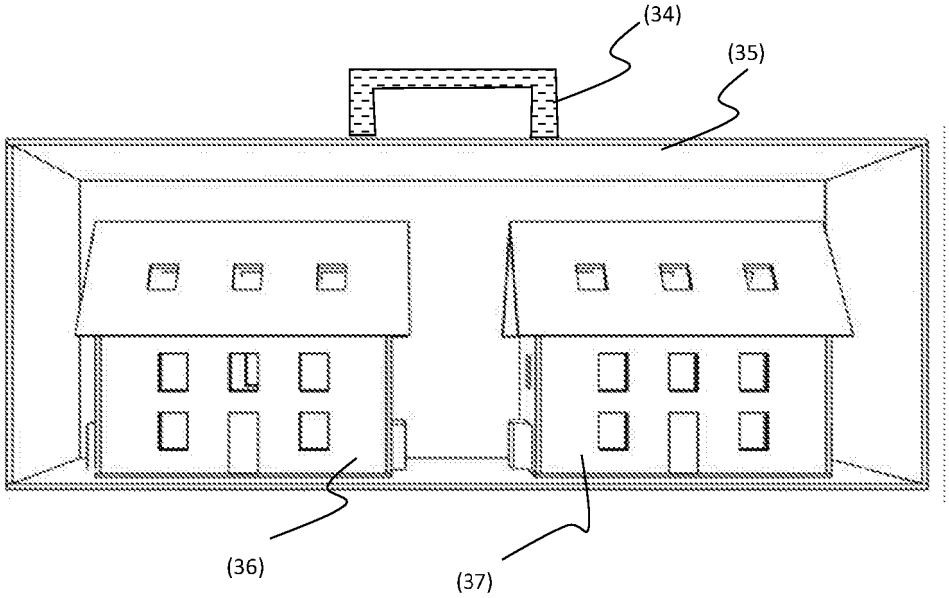

Figure 6

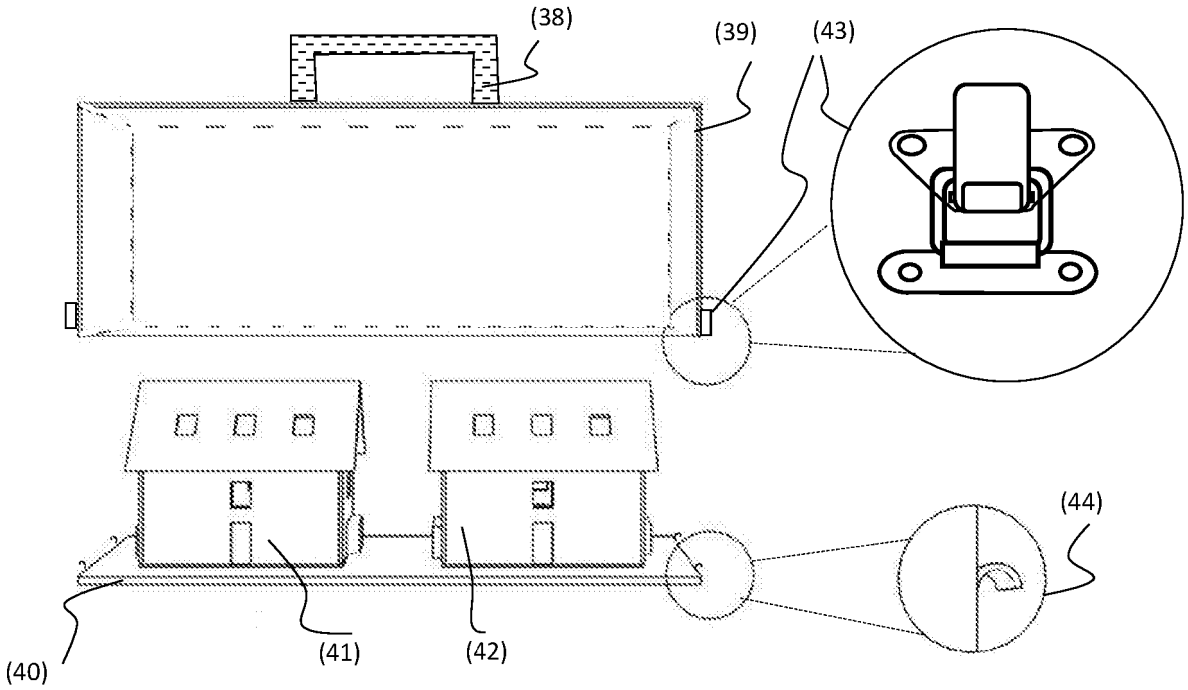

Figure 7

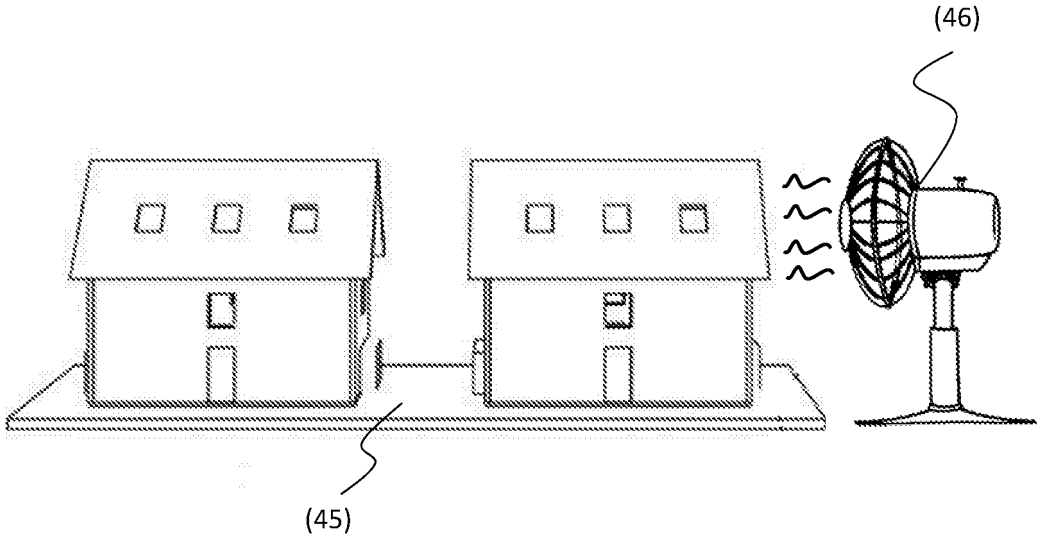

Figure 8

An educational and research apparatus for simulating thermal performance and energy efficiency of buildings

DESCRIPTION

BACKGROUND OF INVENTION

The field of invention is related to enhancing the understanding of the thermal efficiency of buildings via the use of an educational kit that comprises modular building models, components and insulation layers with associated heating and cooling systems as an educational, training and research tool. Reducing carbon emission and energy consumption in buildings is becoming an important priority on global level. Teaching students, researchers and the public on the effect of insulation and other changes in building features on energy consumption is becoming essential to improve scientific knowledge and public engagement. The patent describes a modular and layered building model which can be easily modified with the introduction of thermal insulating layers and with an internal and external control of heating and cooling of the building model and the associated control of the simulated or realistic external environment. There is a gap in the current state-of-the-art in research and teaching tools in relation to developing a modular teaching and research system that could enhance the understanding of the effect of altering the building envelope on the energy performance and thermal efficiency. The educational kit or apparatus will enable a simplified teaching of the value of energy and insulation, this is in addition to the architectural and product design learning skills and knowledge. The modular design allows insulation layers and building components to be interlocking and interchangeable to allow ease of modification, assembly and disassembly.

Statement of Invention

This patent describes a modular teaching and research apparatus for buildings' insulation and thermal performance which is based on a small scale building model as a physical simulator with modular insulation system with interlocking and interchangeable design capabilities, combined with a variety of sensors and heating and cooling processes for developing the thermal simulation process for studying the effect of the change in the environment and the characteristic of the building envelop on energy performance.

The Advantages

In most cases, teaching and research tools for studying and simulating thermal performance in buildings are based on a single component or material based systems to test and measure insulation. In other situations, software-based simulation and modelling is used. Both scenarios fail to engage students and the public in relation to the effect of insulation and modification of building features on energy consumption and the temperature of the building, particularly for the younger generation. This suggested educational tool combines a layer or more of detachable, interlocking and interchangeable insulation, combined with heating and/or cooling of the external and the internal volumes inside and outside the building to study the power consumption and the thermal parameters of the building. Developing the training process on real buildings are costly and time

consuming, with difficulty in influencing the external environment. Computer simulation is normally based on assumptions and does not fully engage the learners in the training and learning process particularly for the younger generation.

DESCRIPTION OF PRIOR ART

It is becoming extremely popular to research, educate, train and engage researchers, students and the public in energy efficiency of buildings in order to help reducing carbon emission and energy consumption. The existing state-of-the-art is limited in this area. For example reference [1] presents software for energy education and a simple models of buildings. The same reference also presents simple single layer models being built by students for testing with infrared thermography. The current state-of-the-art lacks a modular and layered design approach to building models to study thermal performance with interchangeable or interlocking capabilities. Also the current state-of-the-art does not solve the problems related to controlling the internal and external environments of buildings using heating or air-conditioning. Other limitations in the state-of-the-art includes the portability of the system and the effect of insulation layers on the same model. This patent also addresses the current limitations with the use of interchangeable components of the building model, insulation layers, control systems and monitoring systems. The monitoring and control can be also done using computer systems and smart mobile phone applications.

SUMMARY OF INVENTION

The invention will now be described solely by way of example and with reference to the accompanying drawings:

Figure 1 shows a 3D example of the disassembled building model showing examples of insulation layers and the assembled layered modular building model;

Figure 2 shows a schematic diagram of the apparatus including the building model and the main components of the temperature regulation, monitoring and control systems;

Figure 3 shows the installation of the insulation layers to two side walls of the building model;

Figure 4 shows the installation of the insulation layers to two main walls of the building model;

Figure 5 shows the installation of the insulation layers to the roof of the building;

Figure 6 shows the overall system with two building models, with and without insulation, contained within an environmental chamber which also acts as a carrier container;

Figure 7 shows the overall system with two building models and a removed cover; and,

Figure 8 shows the overall system with two building models, with open cover and an electric fan for air circulation.

Turning now to Figure 1, a building model without insulation 1 can be improved by adding several layers of insulation to walls 2 and insulation to the roof 3; the building model can be completed with the external roof 4 that contains windows 5. The insulation layers can all be assembled to a complete insulated building 6 with several internal insulation layers, shown as 7 and 8. The original building material and insulation can be designed from a wide range of materials and colours to

study the effect of material type and colour on the thermal performance of the model. The building components and insulation layers are designed to be interlocking and interchangeable to allow ease of design, assembly and disassembly by the non-expert user.

Turning to Figure 2, a schematic diagram is shown for the concept of operation. The original building model 15 can have one or more insulation layers 16; internally the building could be heated by an electric heater 19 or heated or cooled by means of a heat pump 20; the heat pump in this case could be a refrigeration cycle heat pump or in most cases Peltier effect solid state heat pump; a temperature sensor 18 is used to monitor the internal temperature. The building model is housed in an environmental chamber 14 with simulated weather conditions using an electric heater 12 or a heat pump 17 for heating and cooling. Temperature sensor 21 is used to monitor the external temperature. A light source 13 is used to simulate solar radiation and heat gain. The sensors and actuators control process could be semi-automated or fully automated by an interfacing process to a data acquisition and controller device 11 that supports an interfacing to a computer system 9. A power supply and power meter unit 10 can be used to power the actuators and monitor the energy consumption; this can be done independently or via the computer system. Infrared thermography camera 24 is used to monitor the temperature of the building model; this can be done directly or through the material of the environmental chamber with the selection of suitable material that allows all or part of the infrared radiation to be transmitted via the material.

Turning to Figure 3, an example of the assembly process of insulation material of layers 25 and 26 to the original building model 27 to show the assembly process. The insulation can be added in layers using a sliding method as in Figure 3; or by using other apparent techniques such as interlocking design, snap fit mechanism, mechanical fasteners, magnetic fixtures or tight fitting dimensions.

Turning to Figure 4, a similar installation process of insulation layers 28 and 29 to partially insulated building model 30 allows a full insulation of walls.

Turning to Figure 5, the internal roof insulation 32 is installed below the external roof 31 to the wall insulated building 33 to create a fully insulated building.

Figure 6 represents two building models, a non-insulated building model 36 and an insulated building 37, enclosed within the environmental chamber; the enclosing environmental chamber's cover 35 acts as a holder with a handle 34 to allow the manual transportation of the complete apparatus.

Figure 7 represents the practical aspects of attaching the cover 39 to the base of the building models 40 via toggle clips as an example. The base 40 could be designed by different materials to simulate different solar or heat absorption process and to simulate the interaction with the building model. The toggle clips could be replaced by other mechanical or magnetic fasteners.

Figure 8 represents the use of a fan 46 to provide air circulation to enable the study of the wind speed on heat gain or loss. In this type of work the platform 45 is detached from the chamber and the external environment around the buildings will be the external environment of the model which could be either indoor or outdoor. The fan could be installed on the platform 45 or separately as suitable.

References:

[1] The Concord Consortium, http://energy.concord.org/product.html**, accessed on 10 May 2016.**

[2] The Concord Consortium , http://energy.concord.org/publication/gbmk.pdf, accessed on 10 May 2016.

Claims:

1. An apparatus that comprises a small scale model of a building or more, with internal and external environments that are monitored by suitable sensors and can be controlled by means of heating or cooling processes, where insulation layers are added to or removed from the building model in a modular and interchangeable manner to allow changes to the thermal performance.

2. An apparatus according to claim 1, where the insulation layers are added using a sliding method, interlocking design, snap fit mechanism, mechanical fasteners, magnetic fixtures or tight fitting dimensions.

3. An apparatus according to claim 2, where several layers of insulation are added to walls and roof of the building model as further insulation.

4. An apparatus according to any preceding claim, where several layers of insulation are added to windows and doors of the building model as further insulation.

5. An apparatus according to any preceding claim, where the insulation layers are constructed from different materials.

6. An apparatus according to any preceding claim, where the insulation can be internal or external to the original building model structure.

7. An apparatus according to any preceding claim, where the colours of the building model are changeable to influence radiation and heat gain and loss.

8. An apparatus according to any preceding claim, where windows of the building model are covered internally or externally by different layers of films.

9. An apparatus according to any preceding claim, where windows are covered with curtains or shutters internally or externally using different materials and colours.

10. An apparatus according to any preceding claim, where controllers are used to automatically control the temperature of the internal and external environments of the building model at a specific level, or maximum and minimum levels.

11. An apparatus according to any preceding claim, where a heating or air-conditioning system is used to control the temperature of the internal and external environments of the building model.

12. An apparatus according to any preceding claim, where wind circulation is used to simulate the effect of wind parameters on temperature of the internal and external environments of the building model.

13. An apparatus according to any preceding claim, where solar radiation is simulated using artificial or natural light to study the effect of solar gain on the building model.

14. An apparatus according to any preceding claim, where more than one building model are used under the same or different environmental or control conditions.

15. An apparatus according to any preceding claim, where the heating or cooling is actuated and controlled automatically by means of a computer system.

16. An apparatus according to any preceding claim, where the heating or cooling is actuated and controlled automatically by means of a thermostat.

17. An apparatus according to any preceding claim, where the energy consumption for heating or cooling of the building model is measured.

18. An apparatus according to any preceding claim, where the internal or external temperatures and light intensities are measured using standalone sensors or computerised systems.

19. An apparatus according to any preceding claim, where the heating and cooling of the building model is controlled by a combination of digital and analogue control systems.

20. An apparatus according to any preceding claim, where the control parameters and building model status are presented on a graphical user interface using a computer system or a smart phone.

21. An apparatus according to any preceding claim, where the building model's temperature is monitored by infrared thermography.

22. An apparatus according to any preceding claim, where the building model is contained in an environmental chamber with controllable temperature and light intensity levels.

23. An apparatus according to any preceding claim, where the material of windows are replaceable and interchangeable by different glazing materials and sizes.

24. An apparatus according to any preceding claim, where the building model structure and insulation components can be assembled and disassembled by a non-expert user.

25. An apparatus according to any preceding claim, where a smart phone or a tablet is used to monitor and control the environmental conditions.

26. An apparatus according to any preceding claim, where a wireless monitoring and control system is used.

27. An apparatus according to any preceding claim, where a solid cover is used to form an enclosing chamber around the building model and a holder for transportation by means of a handle.

28. An apparatus according to any preceding claim, where a soft cover is used to form an enclosing chamber around the building model.

29. An apparatus according to any preceding claim, where the cover of the enclosing chamber is removable to allow an open natural external environment.

30. An apparatus according to any preceding claim, where the internal or external heating or cooling processes are performed by means of heat pumps.

31. An apparatus according to any preceding claim, where the internal and external heating processes are performed by means of electric heaters.

32. An apparatus according to any preceding claim, where the material of the external cover allows the transmission of infrared radiation for the use with infrared thermography camera .

33. An apparatus according to any preceding claim, where the external cover of the enclosing chamber has relatively a small opening that allows the transmission of infrared radiation for the use with infrared thermography camera .

34. An apparatus according to any preceding claim, where the building model is built on a platform with variable thickness and material type.

35. An apparatus according to any preceding claim, where the external wind speed around the building model is controlled by means of an external actuator.

36. An apparatus according to any preceding claim, where the cover of the enclosing chamber is fixed to the building model's platform by means of a mechanical fastener .

37. An apparatus according to any preceding claim, where the cover of the enclosing chamber is fixed to the building model's platform by means of a magnetic fastener .

38. An apparatus according to any preceding claim, where solar photovoltaic panels are used on the building model to generate electricity.

39. An apparatus according to any preceding claim, where the building model's temperature is monitored by a temperature sensor.

40. An apparatus according to any preceding claim, where the light intensity on and in the building model is monitored by light sensors.

Amendment to Claims have been filed as follows

Amended Claims:

1. An apparatus that comprises a small scale model of a building or more, with internal and external environments that are monitored by suitable sensors and can be controlled to specific target temperature levels by means of heating or cooling processes, where insulation layers are added to or removed from the envelope of the building model internally or externally in a modular and interchangeable manner to allow changes to the heat transfer process and the actual thermal performance of the building models.

2. An apparatus according to claim 1, where the insulation layers are added using a sliding method, interlocking design, snap fit mechanism, mechanical fasteners, magnetic fixtures or tight fitting dimensions.

3. An apparatus according to claim 2, where several layers of insulation are added internally or externally to walls, roof windows, doors and floor of the building model as further insulation.

4. An apparatus according to any preceding claim, where several layers of insulation are added to windows and doors of the building model as further insulation.

5. An apparatus according to any preceding claim, where the insulation layers are constructed from different materials.

6. An apparatus according to any preceding claim, where the insulation can be internal or external to the original building model structure.

7. An apparatus according to any preceding claim, where the colours of the building model are changeable to influence radiation and heat gain and loss.

8. An apparatus according to any preceding claim, where windows of the building model are covered internally or externally by different layers of films.

9. An apparatus according to any preceding claim, where windows are covered with curtains or shutters internally or externally using different materials and colours.

10. An apparatus according to any preceding claim, where controllers are used to automatically control the temperature of the internal and external environments of the building model at a specific level, or maximum and minimum levels.

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13. An apparatus according to any preceding claim, where solar radiation is simulated using artificial or natural light to study the effect of solar gain on the building model.

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17. An apparatus according to any preceding claim, where the energy consumption for heating or cooling of the building model is measured.

18. An apparatus according to any preceding claim, where the internal or external temperatures and light intensities are measured using standalone sensors or computerised systems.

19. An apparatus according to any preceding claim, where the heating and cooling of the building model is controlled by a combination of digital and analogue control systems.

20. An apparatus according to any preceding claim, where the control parameters and building model status are presented on a graphical user interface using a computer system or a smart phone.

21. An apparatus according to any preceding claim, where the building model's temperature is monitored by infrared thermography.

22. An apparatus according to any preceding claim, where the building model is contained in an environmental chamber with controllable temperature and light intensity levels.

23. An apparatus according to any preceding claim, where the material of windows are replaceable and interchangeable by different glazing materials and sizes.

24. An apparatus according to any preceding claim, where the building model structure and insulation components can be assembled and disassembled by a non-expert user.

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33. An apparatus according to any preceding claim, where the external cover of the enclosing chamber has relatively a small opening that allows the transmission of infrared radiation for the use with infrared thermography camera .

34. An apparatus according to any preceding claim, where the building model is built on a platform with variable thickness and material type.

35. An apparatus according to any preceding claim, where the external wind speed around the building model is controlled by means of an external actuator.

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37. An apparatus according to any preceding claim, where the cover of the enclosing chamber is fixed to the building model's platform by means of a magnetic fastener .

38. An apparatus according to any preceding claim, where solar photovoltaic panels are used on the building model to generate electricity.

39. An apparatus according to any preceding claim, where the building model's temperature is monitored by a temperature sensor.

40. An apparatus according to any preceding claim, where the light intensity on and in the building model is monitored by light sensors.

Intellectual Property Office

Application No:	GB1610666.8	**Examiner:**	Mr Ralph Plowman
Claims searched:	1-40	**Date of search:**	29 November 2016

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	All	EP0032250 A1 (GRUENZWEIG HARTMANN GLASFASER) See EPODOC and WPI abstract accession number 1981-G8313D.
X	All	US2326194 A1 (BARTON) See whole document.
X	All	US4095454 A1 (FISHER) See whole document.
X	All	US4152847 A1 (PFEIFFER) In particular see figure 3.
A	-	CN203225053 U (XI AN HAIZHOU) See EPODOC and WPI abstract accession number 2013-W85334.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

G09B

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI, internet

Intellectual Property Office

International Classification:

Subclass	Subgroup	Valid From
G09B	0023/16	01/01/2006
G09B	0025/04	01/01/2006