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Building services cabinets as teaching material in a degree in architecture

César Martín-Gómez[a], Omayra Zapata[a], Amaia Zuazua[a], Sonia Villanueva[a] & Paula Olaizola[a]

[a] Escuela Técnica Superior de Arquitectura de la Universidad de Navarra, Univesidad de Navarra, Ctra. del Sadar s/n, Pamplona 31008, Spain

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Escuela Técnica Superior de Arquitectura de la Universidad de Navarra, Univesidad de Navarra, Ctra. del Sadar s/n, Pamplona 31008, Spain

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The aim of this innovative educational project is to encourage students' interest in one of the most underrated fields of architecture: building services. With this material students interact with real elements and thereby understand the relationship between facilities and the building. A set of three small technical cabinets is planned. They allow for comfortable use and movement inside the building, need minimum maintenance and are easily stored. The result is an alternative concept of a mobile laboratory called a 'technical cabinet', made up of three mobile units for fire safety, electricity and the heating/cooling system. The design, content and learning systems of the cabinets confirmed the validity of the initial concept during the first year of use. A protocol has also been developed for each of the technical cabinets so that the teaching experience may be of use in other Schools of Architecture.

Keywords: architecture; learning; fire safety; electricity; heating cooling

1. Introduction

Education in a School of Architecture (for both architects and building engineers in Spain) has to cover all fields involved in construction, from design theories to technical areas such as structural design (Isorna 2002) (Figure 1).

In this academic context, which is even more complex due to the teaching of energy management and security, knowledge of facilities and energy in buildings represents an area of design which integrates all the tools to be found in the building domain (Lyle and Albert 2005).

This experience is intended as a novel means of making building services more attractive to students through hands-on learning.

2. Background

The goal of the Building Services and Energy Section of the School of Architecture where this experience has been carried out is that newly graduated students will have been trained to design, calculate and integrate the various building-related services.

Although it is unusual for an architect to receive such intense training in Building Services (Martín-Gómez and Eguaras 2011; Martín-Gómez and Mambrilla 2011) over four years, we

*Corresponding author. Email: instetsaun@unav.es

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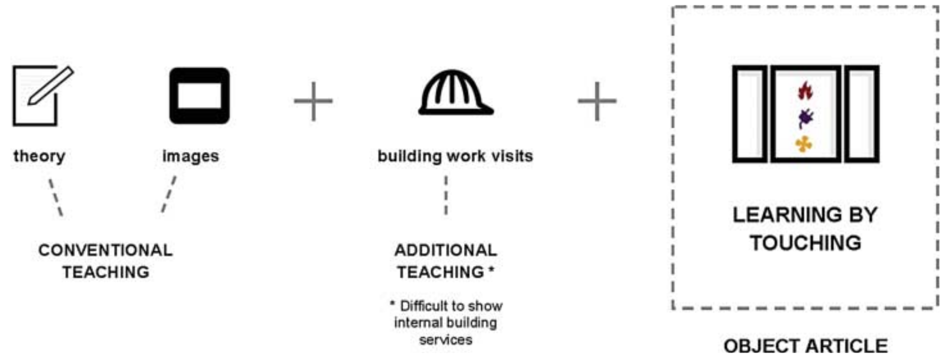

Figure 1. Graphical abstract. Optimum technical learning stage of an architecture student.

intended to offer the students further practical knowledge by bringing simplified real Building Services elements closer to the lecture room.

The three technical cabinets contain the most common facilities in buildings of a certain size: fire safety, electricity and a heating/cooling system.

3. Cabinet use

To ensure students understanding of the content, as well as the maintenance of the cabinets, operational protocols in both Spanish and English have been written; we have included both languages because we hope to achieve the widest possible distribution of this tool, which is intended for use by non-experts and is open to continuous improvement from other working groups with similar concerns. Thus, the tests always follow the same specific logical order, both for student practice and for anyone else who uses them. Two examples: first, these technical cabinets have become a useful marketing tool for attracting future students. They are widely used for teaching by those responsible for Building Services. Second, at a professional level, it is notable that the Fire Department of the Government of Navarra has shown an interest in the fire safety cabinet.

Although in this School of Architecture facilities are taught from the second academic year (Second Year: Fire Safety/Third Year: Electricity/Fourth Year: Heating, Ventilation and Air Conditioning (HVAC)/Fifth Year: Building Services Design), it is during the last year that students have to design and integrate all facilities into their projects. This is when most questions and problems arise, and it is in this final year that the cabinets are used.

For the students to learn through hands-on experience, they meet in groups of less than eight, so that everyone can practice following the guidelines of the protocols.

Each time, before testing, the different components of the cabinets are explained.

The three cabinets have hidden wheels for use in different places and positions within the School Laboratory, and even outside.

Both the high number of students and the anticipated mobility of the cabinets have led to their construction with solid, durable materials, which ensure low maintenance costs and high reliability despite intensive use.

4. Fire safety cabinet

Fire protection is, unfortunately, perhaps one of the least discussed technological elements at Schools of Architecture. That is why in addition to theoretical teaching, practical instruction, as in the case of this technical cabinet, is of the greatest importance.

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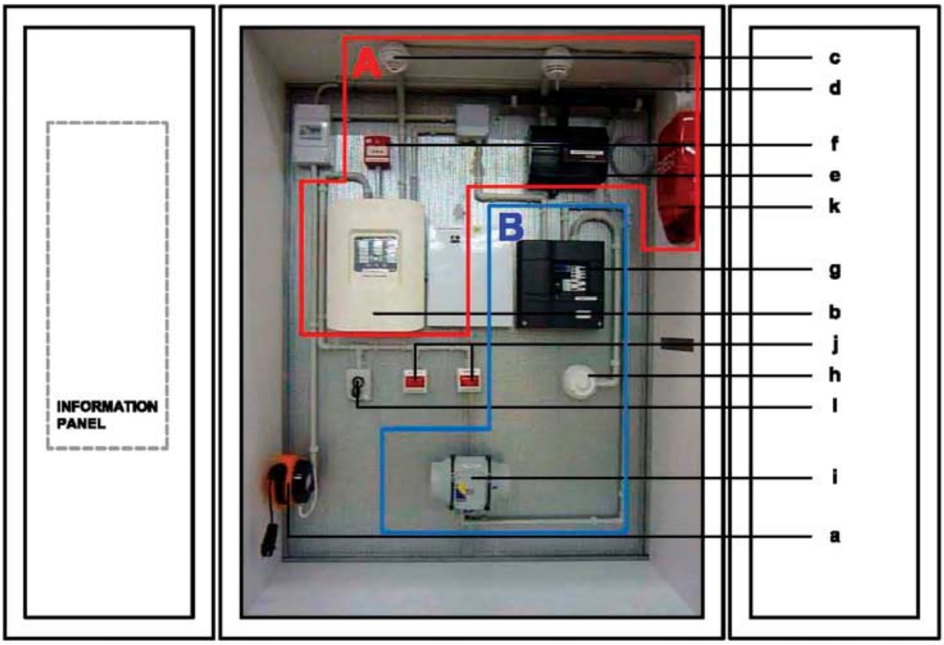

Figure 2. Fire safety technical cabinet.

In this technical cabinet, a fire detection installation is shown with two different sections:

A. Fire detection in a building.
B. Carbon monoxide (CO) detection in an underground parking lot (Figure 2).

The elements shown in this cabinet are the following:

a. Power input. Supplies all elements of the cabinet.
b. Fire alarm panel. An electronic device where detection and activation elements are connected, it receives the signal in the case of fire.
c. Thermovelocimeter detector. Activated when there is an increase in temperature over a certain period (about 10°C per minute).
d. Ionic smoke detector. Detection only begins when the air ionisation and air current are reduced or interrupted by smoke inside the ionisation chamber.
e. Aspiration detector. This unit takes air samples through thin pipes and conducts them to a detector module. The alarm is triggered at a particular smoke density.
f. Call point. Element for manual activation of the fire alarm.
g. The CO detector installation is an installation of general use in underground parking lots. The one chosen here has the following elements:
   h. CO unit. Electronic device responsible for centralising information on CO concentrations and activating the security systems.
   i. CO detectors. Placed every 200 m^2, between 1.5 and 2 m high and at representative locations (in Spain, precise location depends on the Occupational Health and Safety regulations in each municipality, so these data are merely a guideline).
j. Extractor. Fan removing stale air from the parking area and expelling it outside. Here, we have left out the pipes, installing only an axial fan.

These elements are studied following four tests listed in the protocol. Three of these tests activate elements automatically and one of them is activated manually. There is an additional thermovelocimetric detector activation test. However, this is not carried out as it must be activated at high temperatures and in addition, the device must be replaced after each test because the interior detection ampule can only be used once.

These tests are as follows:

Test 1. Ionisation detector. The student proceeds to activate the detector using an artificial smoke spray. When detection occurs, the light signal (i) and acoustic signal (j) are activated. In this test, we must point out the very different effects on the students of the stress caused by the loud acoustic alarm signal. To deactivate the alarm, a password is keyed into the fire alarm panel. The cabinet also has a device that acts as a fire door retainer (k), which is magnetised until the alarm is triggered. It falls automatically, mimicking the lockdown of the sector with, for example, a fire-resistant door.

Test 2. Aspiration detector. This test is similar to the first. In this case, detection occurs when the student sprays smoke directly into the suction pipe (usually found inside the false ceiling). The smoke flows through the pipe to the detection device and the light and acoustic signal come on. The deactivation procedure is the same as in the former test.

Test 3. CO unit. In this case, the suction system is manually activated as it is impossible to have relevant quantities of CO at our disposal. In real life, it would be programmed to go off when a certain level of CO is detected. In Spain, this criterion also depends on each municipality.

Test 4. Pushbutton. The activation is produced by pressing this button. When the acoustic signal activates, it cannot be deactivated until the students reset the pushbutton.

5. Electricity cabinet

Electrical and electronic cabinets are obviously widespread in the field of engineering (Hodge, Hinton, and Lightner 2001), but not in the field of architectural teaching. Moreover, given their small volume in relation to the building or comparing them with other facilities such as air conditioning, they are not considered as important as they should in our society, because electricity is the 'blood of energy' that feeds our cities (Martín-Gómez 2006) (Figure 3).

This cabinet is a simplified diagram of the electrical system used in any home; more specifically, a home with high levels of electricity consumption under the Spanish regulation Reglamento Electrotécnico de Baja Tensión (REBT), Instrucciones Técnicas Complementarias (ITC) 10.2.1,

> corresponding to homes with a foreseeable use of electrical appliances which is higher than the basic electricity supply or which foresee the use of electric heating or air-conditioning systems or with a floor-space of over 160 m^2, or any combination of the above.

We should take into account that the subject Building Electrical Services is taught in the fourth year of Architecture and the third year of Building Engineering, and in both cases, teaching is based on the REBT and its requirements. As an example, dwelling has been chosen because it is the best way to show the elements which appear in any building and thus can be used as the basis for other more complex electrical installations (Figure 4).

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Registro de Pruebas Armario Técnico PROTECCIÓN CONTRA INCENDIOS Nº. ______
Technical Cabinet Tests Record FIRE SAFETY

Responsable
Responsible (R) ____________________ Fecha
Date __/__/ 20__

Iniciar pruebas (R)
Start tests (R)

- ☐ Enchufar acometida
  Plug in connection
- ☐ Subir diferencial (ICPM)
  Pull up differential (ICPM)
- ☐ Una vez activada la alarma sonora pulsar **Enterado**
  Once audible signal is activated push *Enterado*
- ☐ Encender luz armario
  Turn on cabinet light

Explicar elementos (R)
Explain elements

- ☐ Ver esquema en armario e información en este cuaderno
  See diagram in cabinet and information in this notebook

Pruebas (Alumnos)
Tests (Students)

Inicio prueba Detector Z2 / Start Z2 Detector test

- ☐ Colocar retenedor
  Put retainer
- ☐ Expulsar el spray de humo en el detector (2-3 cm)
  Spread the smoke spray into detector (2-3 cm)
- ☐ Una vez activada la alarma, verificar retenedor y señal luminosa.
  Once alarm is activated, check retainer and light signal
- ☐ Para desactivar la alarma, pulsar cuatro veces Tecla 2, **Intro** y **Rearme**
  To desactivate the alarm, push 2 key four times, Intro and Rearme
- ☐ Posteriormente, se accionará la señal acústica *avería alimentación* y se pulsará **Enterado**
  Subsequently, the acoustic signal *avería alimentación will be* activated and Enterado will be pushed

Inicio prueba Detector Z3 / Start Z3 Detector test

- ☐ Soltar tapón del tubo y expulsar spray por el orificio
  Remove the pipe plug and spread the spray into the hole
- ☐ Una vez activada la alarma, verificar retenedor y señal luminosa
  Once alarm is activated, check retainer and light signal
- ☐ Para desactivar la alarma, pulsar cuatro veces Tecla 2, **Intro** y **Rearme**
  To desactivate the alarm, push 2 key four times, Intro and Rearme

Inicio prueba Detector CO/ Start CO Detector test

- ☐ Accionar central CO pulsando el botón, aparecerá iluminado *Auto,* se vuelve a pulsar y se iluminará *Manual*
  Activate CO central by pushing the button, *Auto* will be illuminated, it is pushed again and *Manual* will be illuminated
- ☐ Finalmente, se pulsa de nuevo y aparecerá Stop.
  Finally, it is pushed again and *Stop* will appear

Figure 3. Fire safety technical cabinet test records and action guidelines.

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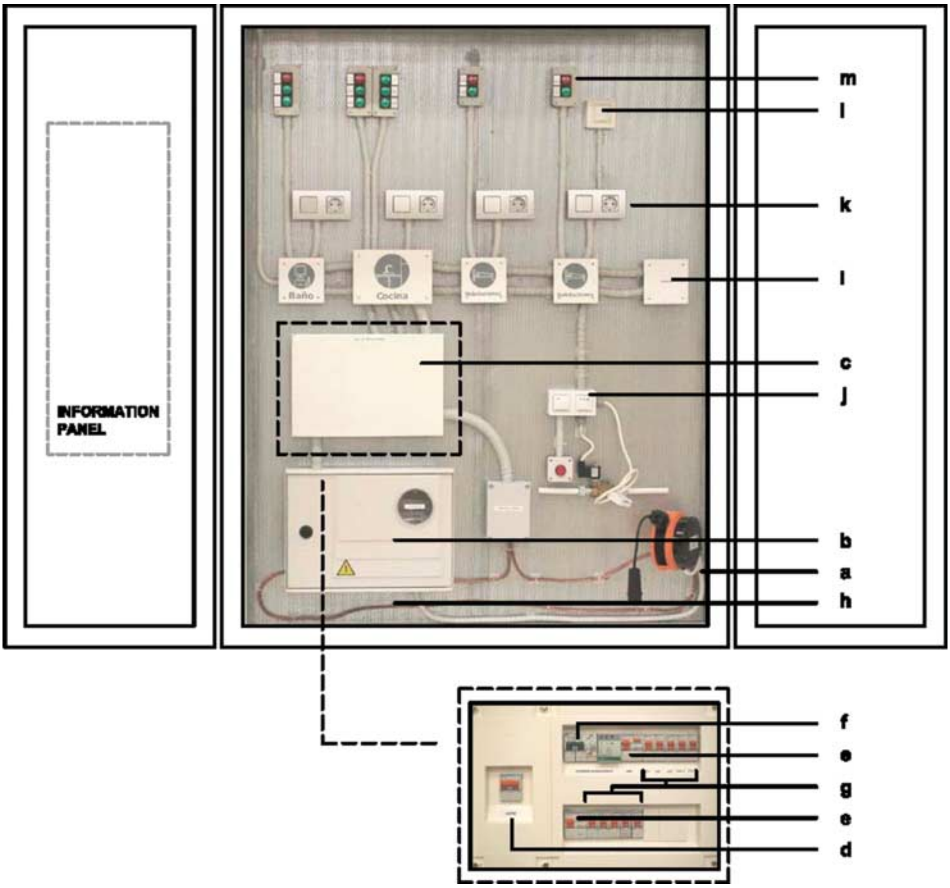

Figure 4. Electrical technical cabinet components and detail of the circuit-breaker panel.

The elements shown in this cabinet are the following:

a. Power input. Supplies all the elements of the cabinet.
b. Metre box. Inside are the single-phase metre and its corresponding circuit breaker.
c. Circuit-breaker panel. Includes magnetothermic and circuit-breaker protectors, as well as the power control switch and overvoltage protector. For a dwelling with a high power demand, the power contracted in Spain is 9200 W. The switch used is rated at 40 A normal operating load.
d. Circuit breakers. Two-pole circuit breakers are installed rated at 40 A and with Alternating Current (AC) type protection (REBT, ITC-25, 2.3. 'A minimum of one circuit breaker with the indicated features will be installed (…) per 5 circuits.'
e. Power surges. The device placed as protection from permanent and transitory power surges has a general automatic switch. This switch, which is an obligatory requirement, is independent of the above differentials. It must be omnipolar with protected poles.
f. Circuits. The installation is divided into 11 circuits, one of which is held in reserve for future additions to the cabinet. Each circuit has an automatic magnetothermic switch which varies from 10 A to 25 A depending on the charge.
g. Grounding. Grounding is simulated by means of a bare copper wire.
h. Branch circuits. Branch boxes are installed to divide the power input to each of the 'rooms'.

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Registro de Pruebas Armario Técnico **ELECTRICIDAD** Nº ☐
Technical Cabinet Tests Record ELECTRICITY

Responsable
Responsible (R) ____________________

Fecha
Date __/__/ 20__

Iniciar pruebas (R)
Start tests

☐ Enchufar acometida* / Plug in connection*
☐ Subir diferencial (ICPM) / Pull up differential (Main switch)
☐ Encender luz armario / Turn on cabinet light

* En el pilar más próximo a la puerta de entrada.
* In the closest column to the door.

Explicar elementos (R)
Explain elements

☐ Ver esquema en armario e información en este cuaderno
See diagram in cabinet and information in this notebook

Pruebas (Alumnos)
Tests (Students)

Iluminación
Lighting

☐ Encender iluminación / Turn on lighting
☐ Apagar iluminación / Turn off lighting
☐ Probar sensor de presencia / Test sensor
☐ Tapar sensor de presencia durante un minuto / Cover the sensor for one minute

El interruptor activa el sensor. Se encenderá la luz roja cuando detecte movimiento.
The switch activates the sensor. Red light will turn on when motion is detected.

Apagar / Encender diferenciales de circuitos de vivienda
Turn on / off differential of home circuits

☐ C1 ☐ C2 ☐ C3 ☐ C4 ☐ C5 ☐ C6 ☐ C7 ☐ C8
☐ C9 ☐ C10 ☐ C11*

* Reserva / Reserve

☐ Probar detector de agua / Test flood detector

Probar funcionamiento de diferenciales
Test operation of differential

☐ Bajar diferencial A / Differential A down
☐ Subir diferencial A / Differential A up
☐ Bajar diferencial B / Differential B down
☐ Subir diferencial B / Differential B up

☐ Provocar cortocircuito (Fase + Neutro)
Cause short circuit (Phase + Neutral)

☐ Provocar derivación a tierra
Cause ground derivation

Salta el diferencial del circuito "máquinas laboratorio" del laboratorio.
Tripped of "Maquinas laboratorio" circuit´s differential.

Finalizar pruebas (R)
End tests

☐ Dejar todos los diferenciales subidos / Leave all differentials pulled up
☐ Apagar luz / Turn off the light
☐ Bajar diferencial (ICPM) / Pull down differential (Main switch)
☐ Cerrar armario contador / Close meter cabinet
☐ Desenchufar armario / Unplug cabinet
☐ Recoger manguera eléctrica / Pick up electric hose

Figure 5. Electrical technical cabinet test records and action guidelines.

i. Flood detector. As an example of a simple control system, a flood detector has been installed which, by means of an electrovalve, would stop the flow of water.
j. Switches and sockets. Switches and sockets are located in each ‘room’. Also, common household items such as an oven, a refrigerator or an air conditioner, with on/off lights, are represented in the kitchen and bathroom. The operation of these appliances is verified using on/off status lighting.
k. Presence sensor. As an example of another lighting item which is becoming more and more common, a presence sensor which turns on the lighting in a ‘room’ is installed.
l. Operating tester. These elements are installed to verify if an item is working when the cabinet is being used.

Tests to be performed are the following:

Test 1. The operation of the lighting system installed in the housing is verified, including the presence sensor.
Test 2. Shows how the circuits divide the electric system and what protections are required. The operation of the circuit breakers for each one is checked. In this section, as one circuit is occupied by an automation system, the flood detector is activated by placing it in a water container.
Test 3. Automatic differential switches are turned on and off.
Test 4. A short-circuit is caused in any of the power inputs by inserting a specifically prepared device.
Test 5. Grounding is produced by students using a purpose-built device.

6. Heating/cooling cabinet

This cabinet covers the entire process of hygrothermal conditioning of a residential space: from thermal energy production in the primary loop, to heat transfer in spaces to be cooled by means of heat sinks (Figure 5).

The HVAC system used is the water–air type, with two different loops:

A. Primary loop. Extracts or transfers heat according to the needs of the space to be conditioned using a heat pump which delivers heat into the hydraulic loop.
B. Secondary loop. Distributes hot or cooled water to the devices located in the rooms to be conditioned (Figure 6).

The elements found in this cabinet are the following:

a. Power input. Supplies all the elements of the cabinet.
b. Air purger. Device used to extract air from a hydraulic network.
c. Fancoil. Medium temperature (50–60°C) heat-sink element. Its airflow passes through the hydraulic loop which carries either heated or cooled water.
d. Dynamic balancing flow valve. Regulates the maximum water flow rate into the fancoil.
e. Pump unit. Raises the head of water. Two different pump types are available in this cabinet: a traditional direct pump unit and a climate mixture pump unit. The latter is similar to the first, but also includes a three-way valve to control the impulsion temperature of under-floor heating (maximum 45°C).
f. Main supply and return header pipe. Distributes water to several circuits to supply different heat-sink elements or secondary loops. Also used as a small hydraulic reserve so the loops have enough flow.

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g. Hydraulic storage. Temporary water storage system, available for consumption.
h. Secondary supply and return header pipe. Supplies water to heat-sink elements.
i. Heat pump. Transfers power in the form of heat between the air and the hydraulic loop by varying the pressure and temperature of water contained in this loop (Miranda 2003). In this case, it is a Kosner heat pump rated at 2.5 kW.
j. Anti-vibration base. Rubber feet which avoid vibration transfer from heating pump to other elements.
k. Under-floor heating. A heat-sink element with a ringed structure that runs under the whole floor, heating the surface.
l. Outdoor temperature probe.
m. Control unit. It schedules a working curve depending on the outdoor temperature probe, controlling both the heat pump and the three-way valve of the pumping of the conditioning mixture. It can also control the heat/cool signal so that heat pump produces heated or cooled water (whichever is applicable).

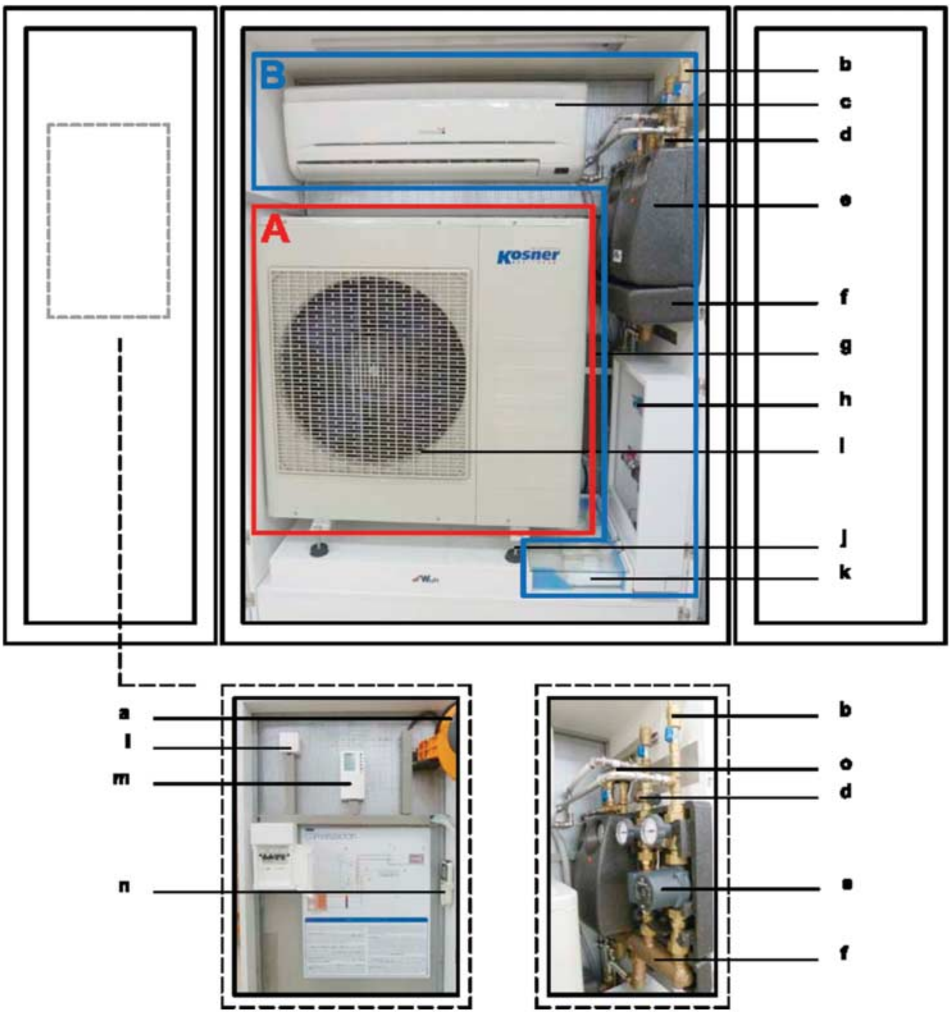

Figure 6. Heating/cooling technical cabinet components and detail of the electrical circuit panel, and the water pumps and pipes.

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Registro de Pruebas Armario Técnico **ACONDICIONAMIENTO** N. ______
Technical Cabinet Tests Record HVAC

Responsable
Responsible (R) ______________________

Fecha
Date __/__/20__

Iniciar pruebas (R)
Start tests

- [ ] Enchufar acometida
  Plug in connection
- [ ] Subir diferencial (ICPM)
  Pull up differential (Main switch)
- [ ] Encender luz armario
  Turn on cabinet light
- [ ] Quitar aislamiento del grupo de bombas
  Remove pump group isolation

Reconocimiento visual de los elementos (Alumnos)
Visual recognition of the elements (Students)

- [ ] Fancoil
  Fan Coil unit
- [ ] Bomba de Calor
  Heat Pump
- [ ] Suelo Radiante
  Radiant floor
- [ ] Sonda Inmersión
  Indoor probe
- [ ] Sonda Exterior
  Outdoor probe
- [ ] Termostato
  Thermostat
- [ ] Colector principal
  Main manifold
- [ ] Grupo de bombeo
  Pump group
- [ ] Válvula de equilibrado dinámico
  Regulating valve

Explicar elementos (R)
Explain elements

- [ ] Ver esquema en armario e información en este cuaderno
  See diagram in cabinet and information in this notebook
- [ ] Distinguir los diferentes materiales de las tuberías
  Distinguish different pipes materials

Pruebas (A)
Tests (S)

- [ ] Seleccionar Calor - Frío en el diferencial
  Select Heat - Cold in the differential
- [ ] Accionar el Fancoil mediante el Botón ON - OFF del mando
  Operate the Fan Coil Unit with the ON - OFF Button of the remote control

Temperatura del sistema / System temperature

- [ ] Verificar la temperatura de agua de los circuitos*
  Verify de temperature of the water system
- [ ] Ver la temperatura de la Bomba de Calor en su pantalla
  See the Heat Pump temperature in its screen
- [ ] Comprobar la temperatura del aire de la Bomba de Calor según la temperatura exigida
  Check the air temperature of the Heat Pump according to the required temperature

**La operación puede tardar varios minutos*
The operation may take several minutes

Flujo del agua / Water flow

- [ ] Distinguir entre las tuberías de ida y retorno según su temperatura
  Distinguish between outward and return pipes according to its temperature
- [ ] Verificar la dirección del agua en las tuberías
  Check water direction in pipes

Figure 7. Heating/cooling technical cabinet test record and action guidelines.

n. Remote control. A remote control is used to manage the temperature and fancoil fan power.
o. Immersion probe. It measures the indoor living-space temperature by checking that the set point is reached.

Learning tests to be performed on this cabinet are the following:

Test 1. Recognition of visual elements. Students know the theory of installations, but they have not yet had the chance to see real devices. In this cabinet, before explaining its operation, they must identify the main elements using the existing diagram.

Test 2. Touch verification of the water flow in pipes. In this test, student must distinguish between the supply and return pipes estimating their temperature difference by touching the pipes that supply the fancoil and floor heating.

Test 3. Checking water temperature in the hydraulic loop. Depending on the mode in which the heat pump is working, either removing or adding heat, the student verifies the temperature of the hydraulic loop as displayed on the thermal screen of the unit (15°C for cooling and 50°C for heating) (Figure 7).

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Figure 8. Technical cabinets closed and stored.

7. Conclusions

The conclusions drawn from the design and operation of the cabinets can be summarised as follows:

- The interest shown by students in participating, touching and interacting with the different components of the cabinets has confirmed the academic value of this innovative educational project.
- This learning system provides new learning dynamics for students and has made the subject more attractive and first hand.
- Simplicity of use and low maintenance mean that the cabinets are not used in just one academic year, but throughout the course of both architecture and building degree studies (Figures 8 and 9).

As this experience has been so successful, we intend to create two new cabinets, one for emergency lighting and the other for water supply services. We must underline the patronage of the company which constructed the cabinets. This is a type of cooperation between companies and universities that should be more commonly shared in Architecture in Spain (Figure 10).

Figure 9. Technical cabinet open.

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Figure 10. Students during a fire safety cabinet test.

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References

Hodge, H., H. S. Hinton, and M. Lightner. 2001. "Virtual Circuit Laboratory." *Journal of Engineering Education* 90 (4): 507–511.

Isorna, J. M. 2002. *Enseñanza y práctica profesional de la arquitectura en Europa y Estados Unidos*. Barcelona: Colegio Oficial de Arquitectos de Cataluña.

Lyle, D. F., and J. R. Albert. 2005. "The Role of the Laboratory in Undergraduate Engineering Education." *Journal of Engineering Education* 94 (1): 121–130.

Martín-Gómez, C. 2006. "Las Instalaciones Y La Arquitectura." *Tectónica* 21: 4–27.

Martín-Gómez, C., and M. Eguaras. 2011. *La necesaria investigación de los sistemas de calefacción urbana en la docencia del urbanismo*. IV Jornadas Internacionales sobre Investigación en Arquitectura y Urbanismo, Universidad Politécnica de Valencia. Accessed 2011. http://hdl.handle.net/10171/19615

Martín-Gómez, C., and N. Mambrilla. 2011. *El dónde y el cuándo de la investigación en protección contra incendios*. IV Jornadas Internacionales sobre Investigación en Arquitectura y Urbanismo, Universidad Politécnica de Valencia. Accessed March 30, 2012. http://hdl.handle.net/10171/21450

About the authors

César Martín-Gómez is a PhD Architect from the Universidad de Navarra (Spain). He has worked in the Architecture Department in the Spanish Renewable Energies Center (CENER), and as Building Services and Energy Coordinator in Mangado & Asociados. Nowadays he works as researcher and professor in the School of Architecture in the Universidad de Navarra.

Omayra Zapata is a building engineer, mechanical engineering student, and assistant in the Department of Building Services and Energy of the University of Navarra, with an internship in the Emergency Agency of Navarra.

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Amaia Zuazua is an architect specialised in Restoration and Renovation of Cultural and Artistic Heritage, and a student of the Master Program in Energy Optimisation for Buildings in Mälardalen University, Sweden.

Sonia Villanueva is an architect, and assistant in Building Services and Energy Section, School of Architecture of the University of Navarra, Spain.

Paula Olaizola is an architect who graduated in 2012 from the School of Architecture of the Universidad de Navarra located in Pamplona (Spain), with extensive knowledge in technical areas related to architecture, such as Structures and Facilities. Some notable collaborations are with the Building Services Department of the University of Navarra and the company Iturralde y Sagüés Engineers.

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