Architectural repercussions of the air conditioning installations

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ABSTRACT

This work aims to present an analysis of architectural repercussions involved in choosing a certain climatic system for an office block. The intention is to unite techniques and the building itself.
Independently of the bioclimatic design criteria for office work, these buildings require active technical systems for their air conditioning. We should only consider the air conditioning option that allows for regulation of areas and the maximum energetic effectiveness (VAV, fan coils, ducted fan coils, etc). The choice of the final system has serious considerations for both the architect and the building.

In this study a representative office floor plan is proposed. Among its features are: an open-plan, certain height, core services and glass retaining wall. For this plan, the different air conditioning systems are analysed focusing on the consequences on the architecture (space occupied, spatial distribution, visual impact, user comfort, etc). These aspects will be studied afterwards for the whole building.

This work will allow us to have a summary of the architectural repercussions of each system so that the architect can take decisions before designing the installation.

Key words: installation, architecture, air conditioning, office block.

1. INTRODUCTION

This work aims to present an analysis of architectural repercussions involved in choosing a hygrothermal conditioning system in an office block with the intention of managing to integrate the technique with the building. These systems are understood to be able to achieve levels of thermal comfort for the user. Thus, the desired well-being can only be achieved in these workplaces if the air conditioning – heating and cooling – and ventilation systems considered are acting on the temperature and humidity of the environment equally and, also, on the air quality.

Aside from the design criteria of a bioclimatic nature to be taken into account in a tall building, all office blocks need active technical systems for their air conditioning.

From among all the possible air conditioning systems, it is decided which are to be considered appropriate for office blocks (Variable refrigerant flow, Variable air volume, etc.). The choice of the final system has serious considerations for both the architect and the building.

2. ANALYSIS

The intention is not to study air conditioning installations in the same manner as is done in technical books – design, layout and calculation – but rather to evaluate the architectural effects that are caused by choosing one particular air conditioning system. While the integration of installations into a building is considered as a whole, the integration of thermal conditioning systems, in particular, is a distinct matter – an element (and not alone, naturally) that creates architecture. *"While, in reality, there is no real conflict between technique and art, a technical standpoint can favour the creation of a more attractive aesthetical form and, on the contrary, an aesthetical approach to a technical or scientific problem that can lead to a less rigid solution"*[1].

How is it possible to consider refrigeration, heating or ventilation without looking at installations for plumbing, sanitation and electricity? It is yet more difficult to detach hygrothermal conditioning installations from domotics, regulation, etc. or from the fire prevention systems. It is complicated to separately study the installations in a building, particularly when the intention is to design integrated complexes. However, while the cross-over between one and the other is clear, the decisions taken in air conditioning installations are the factors that will have most influence on the configuration and workings of the building.

Given that the use of this type of installation is obligatory when considering offices and as the block is a model that is easily systematised, office blocks constructed in the first decade of the 20th century in Spain – and, due to their relative geographical closeness to the authors, specifically the triangle formed by Barcelona, Zaragoza and Madrid – have been chosen as the area of study. As it is only possible to establish the basic principles from a combination of intellectual analysis and practical application of what happens with air conditioning installations, the installations of various emblematic buildings have been examined, among them:

- Torre Llacuna, Barcelona (project from 2001)[2]
- New headquarters of Gas Natural, Barcelona (2006)[3].
- World Trade Center, Zaragoza (2008)[4].
- Cuatro Torres Business Area (CTBA), (2007-2009), Madrid[5].
- Office block in the Aragonia building, Zaragoza (2010)[5].


Fig. 01. Glass Tower. (Madrid)


Fig. 02. WTC (Zaragoza)


Fig. 03. LlacunaTower (Barcelona)

All of the cited buildings correspond to a representative model of one floor in an office block: an open-plan, certain height, core services and glass retaining wall. With such a configuration, the different air conditioning systems employed were analysed, studying the architectural consequences arising from the choice of each of them (space occupied, spatial organisation, visual impact, user comfort, etc.). The elements analysed for the one floor are broadened, later, to cover the whole block.

If all the installations in a building were regulated by a broad, complex and variable regulation, there is no doubt that in Spain many of the aspects regulated by the Rules for Thermal Installations in Buildings (R.I.T.E.)[7] would affect architectural considerations when designing an office block. Assuredly, the Basic Safety Document, in situations of fire, (DB SI)[8] from the Building Technical Code (Spain), which is strongly linked with hygrothermal conditioning installations, is one of the regulations that most condition design in a tall building.

In office blocks, the current regulations regarding the area of fire prevention have lead to a significant increase in the area occupied by core services – those which normally consist of two staircases, lifts, installation rooms and utility shafts, in addition to the corresponding ventilated lobby. However, the demands of the DB SI regarding the sectioning of buildings are what most condition the organisation of air conditioning installations.

In order to fulfil the R.I.T.E. technical requirements and of all the possible alternatives for thermal air conditioning, the office blocks under consideration – glass-fronted buildings all – can only be equipped with those that allow for control by zones and maximum energy efficiency. The aim is to consume what is needed for optimum comfort at all times.

However, the need to bring in treated air from outside and energy recovery are the requirements that have the greatest impact – particularly spatially – on buildings.

As regards the fluid energy carrier that reaches office areas, the systems considered to be adequate for conditioning these buildings are:

- Of the water-air systems: fan coils, inductors and cooling units.
- Of water-only systems: unventilated fan coils. This requires separate installation of an air recovery system.
- Of the systems using refrigerating gases as a heat-transporting fluid: the Variable Refrigerant Flow (VRF) – using Inverter Technology.
- Of the air-only systems: those with varying flow, i.e. those that are Variable Air Volume (VAV).

When considering the generation of cold or heat, boilers, compression-cycle refrigeration, air and water refrigerated heat pumps and heat exchangers are the high performance equipment that should be examined[9].

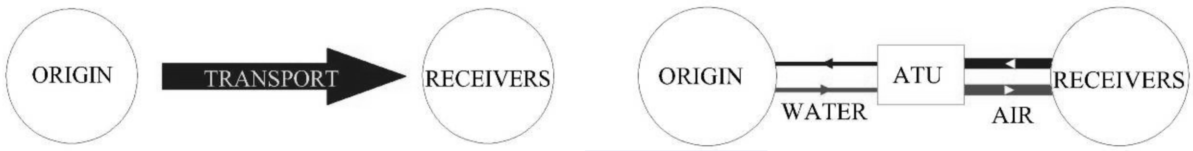

Fig. 04. General patterns.

In order to structure the explanation of the architectural repercussions that air conditioning installations have on an office block, it is considered that whatever the system may be there will always be an origin, a transport factor and a receiver. The origin is the heat or cold-generating equipment and this is where the transport flow originates. The transportation components consist of pipes or ducts which transport the heat-transporting fluid – water, air or refrigerant – and impose resistance in the circulation to the receivers. The receivers are the elements which receive the fluid transported: air treatment units (ATUs) and terminal units found in the areas to be air-conditioned[1].

The installations in general, but above all those for hygrothermal air conditioning, determine the building in which they are housed. However, the networks of services and the air conditioning systems should not be considered a nuisance that must be hidden and do not form part of the architecture; instead, a place should be found for them. Only from knowledge of the installations, their configuration and their repercussions on construction can the subservient and servicing areas be integrated as analysed by Louis I. Kahn, who wrote of the Richards Memorial laboratories project: *"I do not like ducts and piping. In fact, I utterly hate them, but because of this I feel that they must be given their place. If you only hated them and were not careful, then I believe they would invade the building and destroy it completely"*[10].

The consequences of the implementation of the air conditioning systems on an office block have effects in the following architectural aspects of the building:

- Spatial repercussions.
- Construction repercussions.
- Environmental and user comfort repercussions.
- Formal or aesthetic repercussions.

The magnitude of these effects will be analysed in the origin, the transportation systems and the receivers in hygrothermal conditioning installations.

3. SPATIAL REPERCUSSIONS

These are undoubtedly the most important for the building. Not only does the block need to be given enough space to emplace the equipment, networks and the other components of the installations, but also these spaces must guarantee good maintenance of these installations and the possibility of future modification or expansion.

Thus, a guarantor of a good result is the over-sizing of shop premises, utility shafts, horizontal galleries, false ceilings and raised access floors, particularly when the complete range of installations in the building has yet to be resolved.

3.1. Origin

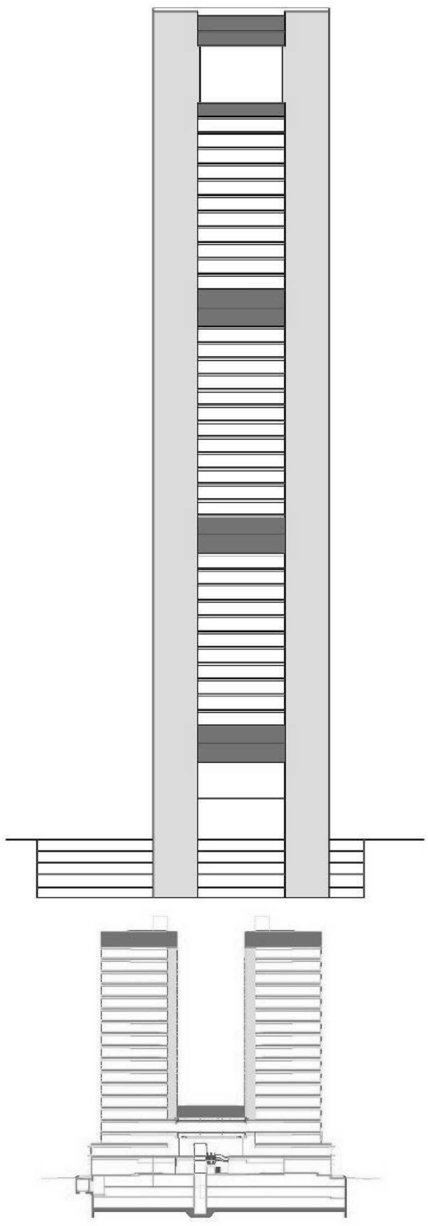

Fig. 05. Mechanical plants situation

When considering the basic schematics for the air conditioning system in a building (whatever that system may be), the first decision is the location of the energy generators. It is just as valid to have cold groups that serve not just the office blocks but also the whole of the different building areas constructed (over 6,000 Kw of cold) – as is the case of the Aragonia complex by R. Moneo – as to consider an installation divided into two levels (WTC by Aranaz Associates) or to decentralise the external units according to floors as with the new Gas headquarters by E. Miralles/ B. Tagliablue. The varying degree of centralisation or decentralisation creates different spatial requirements: these can range from reserving one or more mechanical plants in the building for this purpose – shared with the rest of the installations – to the roof(s) of the block or specific rooms on each floor (size approximately 7 m^2 in the Gas headquarters). The floors for installations can be located in the basement of the building or through the block depending on the degree to which the installation is divided. In order not to make the installation more complicated, only coolers or water-refrigerated heat pumps should be placed in the basement; where there are boilers, there should be a smoke evacuation pipe in the roof.

In the case of ventilation installation, the ventilators are located on the roof. The tendency is to introduce the necessary air for each floor naturally or mechanically – in which case smaller ventilators are placed in the false ceilings of the offices.

3.2. Transport

The transport systems occupy different spaces depending on the fluid to be displaced around the block – water, refrigerant or air – and the level of centralisation/decentralisation of the block.

The centralised hygrothermal conditioning installations require vertical utility shafts and horizontal galleries to house the pipes – in the case of hydraulic circuits – or ducts – if air is being transported. If the level of centralisation refers to each of the floors in the block, the networks run through the accessible false ceilings or the raised floors.

If there are vertical columns, then the most typical is that these are configured together with the core services – correctly sized – without weakening the fire resistance of the lift, stairs and independent lobby enclosures so as to maintain complete accessibility – as described by F. Rafeiner in his study in 1969[11]. Other innovative solutions include housing the vertical fluid transportation within the façade of the building or in raised walls.

Almost all administrative buildings have accessible false ceilings and floors for the distribution of air conditioning installations – and the other installations – around each of the office floors. As an example, there is the Glass Tower which has 70 cm of false ceiling and 40 cm of raised floor.

The larger volume occupied by the air ducts – compared to the water or refrigerant circuits – and the need for sectioning every three floors (requiring the emplacement of accessible fire doors) reduces the use of air distribution systems to the floors in most cases. Energy transportation through the block is normally achieved through hydraulic or refrigerant circuits.

The regulatory needs to bring in treated air from outside and to recover heat prior to expelling the extracted air complicates the air networks and demands greater spatial consideration.

The entrance of the renewing air through the framework thickness of each of the floors avoids the use of large ducts – as has happened in the Glass Tower.

The greatest limiter to be considered in the VRF systems is the maximum length of the refrigeration pipes – see the corresponding Spanish regulation to AENOR – to which L. Jesús Arizmendi referred as follows: "*Currently, the maximum distance between the exterior unit and the longest between interior units is of 100 m measured along the refrigerant pipe. Vertically, the maximum allowable distance is of 50 m between the exterior and the interior units and of 15 m between two interior units connected to the same exterior unit*[12]".

The energy transport networks – pipes and air ducts belonging to the office air conditioning system – are complex – circuits weaving back and forth – as well as having independent extraction for the services areas and the pressurisation of the stairs and independent lobbies, should these lack natural ventilation.

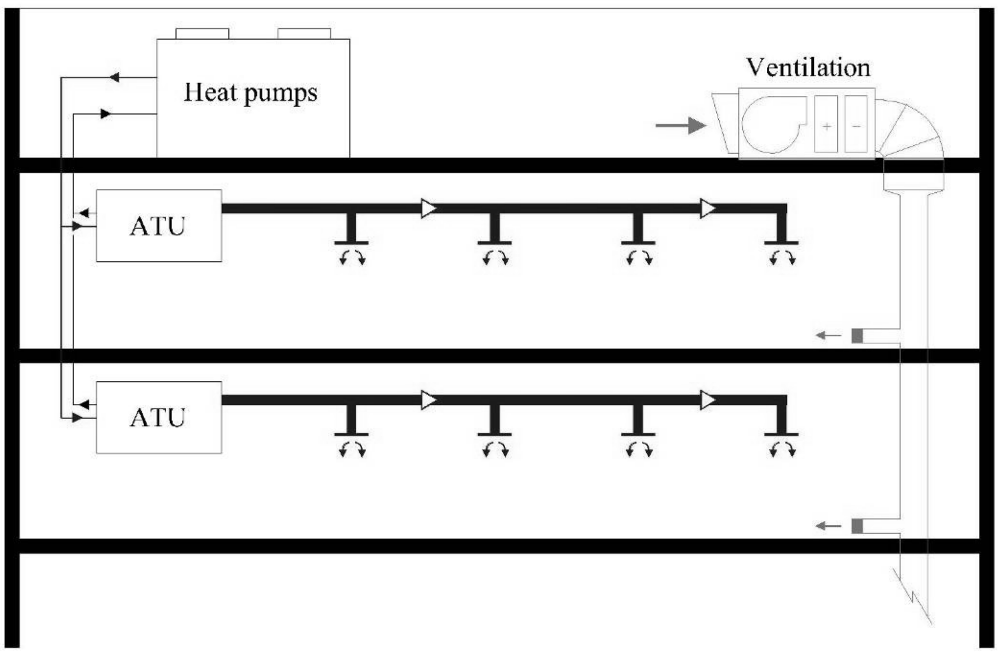

Fig. 06. Facilities Llacuna Tower. Water-air system. Unventilated Fan coils.

3.3. Receivers

There are many types of interior units on the market: ceiling-mounted, vertical floor units, horizontal on the ceiling, wall-mounted, embedded in the false ceiling and connected directly to diffusers and grilles. There is a clear trend towards placing the terminals in the false ceiling – depending on the space available. There are also slim-line models on the market with a height of 300 mm.

One final consideration might be a VRF-AIR system – placing interior units in the false ceiling or in specific rooms – not going into offices – and, from there, distributing to all areas via a network of ducts, diffusers and grilles which would distribute the air to all areas.

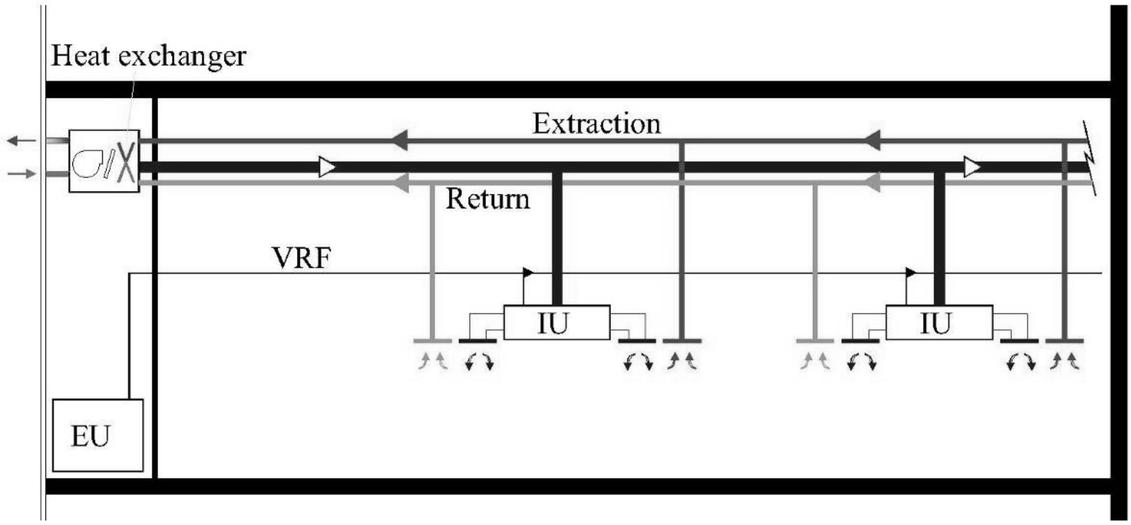

Fig. 07. Facilities headquarters of Gas Natural. System VRF. Ventilated fan coils.

The grilles and diffusers are normally housed in a false ceiling, but they can also be placed in a raised floor – and they do not require space specially set aside.

4. CONSTRUCTION REPERCUSSIONS

The effects of the implementation of air conditioning installations on construction aspects of an office block are important and basically refer to three areas: the structure calculations for the block; the solution to the enclosing elements to avoid noise pollution to nearby buildings and within the building itself; and the definition of the support system elements required to avoid noise and vibrations being transmitted within the building itself.

The correct dimensions of the structure anticipating the exact location of the equipment – particularly the roofing thickness or floors of the mechanical plants – are necessary as the emplacement of the generators depends on this.

While office blocks require large urban areas due to their heights, the noise caused by the machines must not be permitted to reach neighbouring buildings. Thus, in the case of emplacing the machines on flat roofs, it is necessary to have the construction definition of the enclosing element for the roof so that it serves as an acoustic dampener so as to avoid transmitting noise to those neighbouring buildings. In the case of raised rooms located in the middle floors of the block, their enclosures must be solved; these have two important purposes: allowing the air in from outside to refrigerate the machines and shielding them from noises that could be transmitted to other buildings – with all the difficulties this implies.

Furthermore, emplacing the machines in the middle floors requires a specific definition of all the enclosing elements in those floors – floors, ceilings and walls – so as to avoid noise being

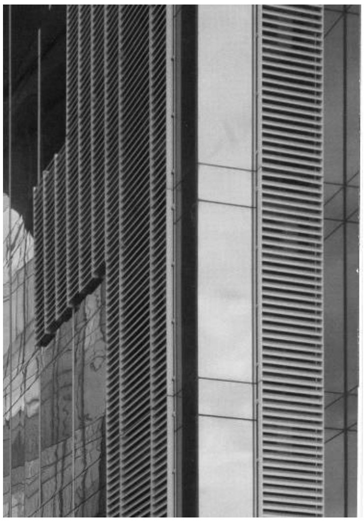

Fig. 08. Gas Natural Building. Ed. Pencil

Fig. 09. WTCZ

transmitted aurally to office floors located below and above those containing installations. Thus, enclosures of a certain mass, soundproofed ceilings and so forth are required.

The decentralisation of machines by floor multiplies the problem but it does reduce the intensity. Where there are rooms on each floor with exterior units or ATUs, a good solution is to place them so they form part of the core services, so that the stairs, lifts, bathrooms and other areas with fewer acoustic requirements than the offices can soften the noise impact of the equipment. Locating the installation rooms in the basement simplifies these matters.

The corrective measures performed to support the thickness of the machines require special attention. There must be a mounting support or independent floating metal structure for each set, able to support the static and dynamic charges from the sets and to greatly reduce the transmission of sounds and vibrations via the structure. The slabs or structures – absolutely flat – lie upon high-density vibration-acoustic soundproofing, which works better if it is not a single continuous piece.

Fig. 10. Aragonia Tower

The utility shafts, horizontal galleries and false roofs should be sufficiently soundproofed. The crossing of pipes through the constructed areas is solved through anti-vibration systems.

In order to achieve the sound levels required by Spanish regulations[13] for administrative buildings, in addition to the construction methods defined in this section, good execution of the installations is necessary as well as the use of systems which conform to the requirements of DB-HR – emplacing flexible and muffling components on machines, pumps, pipes and ducts[14]. However, the use of adequate materials and accessories available on the market neither require spatial nor construction considerations of note.

The double façade retaining wall used in the Glass Tower or the Space Tower, for example, is a construction system that, in addition to its vocation as a passive air conditioning element, works completely to provide new air and the air for the air conditioning system.

5. ENVIRONMENTAL AND USER COMFORT REPERCUSSIONS

In this section, the main functions of hygrothermal conditioning installations are considered: achieving the temperature and quality of air necessary in the office so that the individual is comfortable and can perform their work to the best of their abilities. There are many repercussions of air conditioning installations, but those that affect living conditions have the greatest consequences on the building's users. There will also be mention of the noise generated by these installations.

The question of comfort is a complex topic that would require a paper of its own considering the number of parameters it covers, the subjective character of the receivers, etc. Thus, this paper will only consider a few matters that are relevant to the administrative building.

5.1. THERMAL COMFORT

Of all the conditioners in the design of office blocks, there are two aspects that determine the comfort parameters for each workplace: the façades of the buildings – all glass or a predominance of large windows in all directions – and the organisation of the large open-plan floors of the office block, with inner and outer areas with a large amount of sunlight. The air conditioning systems should achieve the optimum air temperature for the needs in each area – having heating and cooling available simultaneously – which will in turn determine the type of installation to use. The control systems should have a good number of zones covered and a large number of areas managed so as to consume the energy needed at the time, adapting to the different areas and the needs of the majority of people who are in the offices.

Proper thermal comfort can only be achieved through correct distribution of temperatures and air speeds, control of the humidity and adequate air quality – i.e. a distribution of air to all parts of the offices – within the occupied area.

The Spanish regulations which decree the comfort parameters and how to calculate these are the R.I.T.E and the UNE-EN ISO 7730 REGULATION.

Interior design conditions[7].

Season	Operational temperature ºC	Relative humidity %
Summer	23 - 25	45 - 60
Winter	21 - 23	40 - 50

Minimum level of external air for ventilation[7].

Category	dm^3 /s per person	dp (air quality)
IDA 2 (Offices)	12.5	1.2

Air speed[12].

	Summer	Winter
m/s	0.18-0.24	0.15-0.20

It must be considered that while the occupied area is viewed as a parallel plan to the floor measuring 1.70 – 2.00 m, the majority of the users remain seated in their workplaces and it is this area at 0.60 m from the floor that is the critical zone which must be closely examined. Direct action upon the user's body by a propulsion discharge pump at a temperature below the ambient temperature is typical. The correct organisation of terminal units, grilles, diffusers and nozzles and the adequate speed to promote air flow are essential. Interior unit designs have been developed that optimise the interior propulsion of the air.

The interior VRF system units, fan coils and ducted fan coils located inside offices must be equipment that allows individual control in each of the areas in accordance with the user's needs. The UI ventilators must have frequency changers so as to adapt to the distinct situations of partial charge.

Multi-split systems allow an exterior unit to be connected to various different interior units, without this meaning individual control being given up. Regulation of interior units can also be done from a central control board in accordance with conditions outside, among other parameters.

The most recent blocks in Madrid are examples of innovative strategies in the intent to optimise user comfort. The active façade of the Glass Tower as a component that accentuates external climate conditions and the emplacement of fan coils around the edges of the offices promote good energy distribution. In the case of Space Tower, moving the air through ventilation in the false flooring and the panel and cold joist system in the roof boosts indoor air circulation.

Whether or not the final user of the office block is known, when an architect has to project a building of this type the flexibility of the spaces has always been a primary design criterion from the beginning right through to today. If the distribution of the receivers of the air conditioning is not conceived from that possible variability, then the unexpected breaking down of an open-plan into individual offices could mean that particular users find themselves in a constantly uncomfortable situation which could lead to consequences of varying degrees.

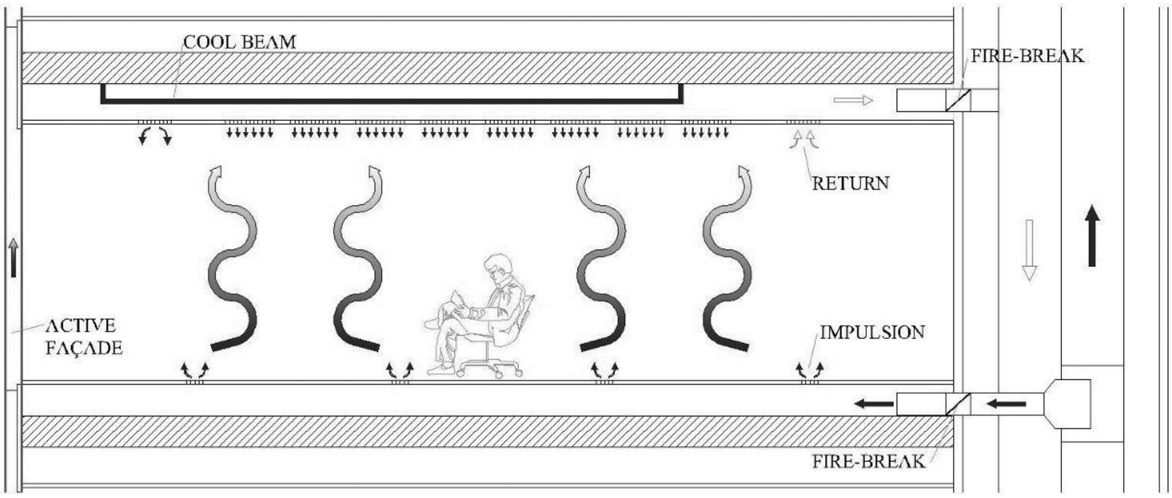

Fig. 11. Distribution air. Space Tower.

5.2. ACOUSTIC COMFORT

Although the sound level in indoor areas in the block depends on many elements, the air conditioning installations – generators, pumps, water and air circulating around the pipes and ducts – are one of the main producers of noise within the building.

In order to achieve the acoustic comfort required and necessary for the user to be happy in the office ($L_{eqA,T}$: 40-50dBA)[14], all of the construction measures indicated in the previous section must be adopted. The coolers, fan coils and ducted fan coils must be of high quality and silent. The grilles and diffuser terminals must not generate a greater sound level than that permitted.

6. FORMAL OR AESTHETIC REPERCUSSIONS

When the impact of air conditioning installations on building aesthetics is analysed, there arises a debate between hiding and revealing the energy. Furthermore, this double debate runs for both the exterior and the interior of the buildings.

6.1. SHAPE OF THE BLOCKS

When deciding the position of the mechanical plants, the architect is considering the exterior image of the block – whether or not the rooms are visualised. Thus, there is the Glass Tower whose glassy, reflective envelope does not reveal what is happening within. Under artificial light, the complete mimesis of the retaining wall façade dissolves and the different uses are revealed. The opposite case is courtesy of N. Foster with the Caja Madrid Tower where the mechanical plants and the core services can be seen, becoming relevant, and configuring the shape of the building.

Complete or rhythmic enveloping and the aim not to reveal the installations implies opting for water condensate generators – being completely hidden is the option for the Aragonia complex.

A middle ground is that of the WTC where the location of the machines on the roofs creates a solid finish for the blocks. The same option – using a light enclosure – is present in the Llacuna Tower in Barcelona, where the opaque strips stand out on the façades as they cover the framework, false ceilings and the installations. Solutions like opaque or mirrored glass allow ceilings and raised floors to be concealed.

The strict air renewal regulation for offices means there has to be a formal consideration when positioning entry points for the air from outside. Either air should be taken from the roofs or, so as to avoid complex networks, it should be brought in on each floor. In the latter case, grilles could be emplaced as a specific element or integrated into parts of the retaining wall – as happened in the Aragonia building or the Glass Tower.

The option of decentralising the placement of the equipment and locating rooms down a vertical strip – as in the case of the new headquarter of Gas Natural – provide the opportunity to design a type of special grille, allowing the necessary influx of air while being integrated with complete normality into the complex of glass façades.

Fig. 12. Caja Madrid Tower. (Madrid)

Fig. 13. Headquarters of Gas Natural (Barcelona). Ed. Pencil

6.2. OFFICE AESTHETICS

The tendency when considering the exterior image of offices is to hide the energy, disguising the terminal units, grilles and diffusers with ceiling strips. Considering the option of leaving the installations open is for other uses and other more expressionistic times.

Nowadays, no office is conceived without a false ceiling or raised floor with the obvious intention of hiding the installations…or maybe leaving them open – for easier maintenance.

On the market there are many types of interior units, the choice of which depends – aside from spatial requirements – a matter of aesthetics. There is a clear trend towards emplacing the terminal units in the false ceiling – achieving a minimal appearance in the room. The grilles and lineal fan coils are placed at the extremes of the floor so as to be as imperceptible as possible. The existence of the regulating components must not be forgotten – detectors, thermostats, etc. – as their presence is unavoidable.

Prior to concluding, it is necessary to note that while the hygrothermal conditioning systems under study are global systems that guarantee the thermal conditions for the workplace environment, it could still be necessary to have independent, specific systems for other subsidiary uses in the office block (auditoria, restaurant, etc.).

7. CONCLUSIONS

Hygrothermal conditioning systems in a block are complex networks affected by a wide range of changing and complicated regulations, for which reason the basic principles of what occurs in air conditioning installations and the architectural repercussions that they can have on buildings must be known so as to correctly integrate them.

Air conditioning installations condition the building in which they are implemented: shape, volume, function, aesthetics and technology.

Of all the building networks, the air conditioning installations occupy the most space. Therefore, predicting and over-sizing the floors, shop premises and spaces must happen from the very beginning of the project.

Furthermore, specific construction solutions are needed for the enclosing elements for the rooms and chambers where the equipment and networks are located.

Shape combined with function can lead to blocks with great expressive qualities.

In common with the other installations in the building, the air conditioning systems condition the user's feeling of comfort – the ultimate receiver of the architectural fact. The system must adapt to the variability of the system and uniformly distribute the energy around the area occupied by people.

The installations are technology and architecture and the much anticipated joining of the two disciplines needs to be achieved among us all. It is time to take advantage of the ideas, the technological innovation, the new energies and so forth as ways of ensuring the installations generate architecture and are not to be considered a nuisance factor within the building.

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