

THERMODYNAMIC INTERVENTIONS

An approach to thermodynamics as a tool for intervention on built industrial heritage through the FRAC Nord-Pas de Calais and the Centre Civic Cristalerías Planell

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During an interview with Alison Sky, Robert Smithson was asked if entropy is in reality a metamorphosis, or rather a continuous process whereby elements experience changes in an evolutionary sense. His answer was:

“Yes and no. It is evolutionary, but not in an idealistic sense (...). I’m not a transcendentalist, I only see that things progress towards... well, it is very hard to predict anything. In any case, all predictions tend to be wrong. I’m even referring to the planning. Planning and chance almost look like the same thing. Architects don’t pay attention to these things. They tend to be idealistic and not dialectic. I propose a dialectics of entropic change¹.

To understand the rationale behind Smithson’s proposition, it is useful to review the works of Luis Fernández-Galiano. In his book *Fire and Memory*, Fernández-Galiano suggests that the introduction of the concept of entropy inherent to the second law of thermodynamics² enables understanding of the tight bond between the degradation of energy and the degradation of matter, shifting the focus to the daily energy consumption of a building during its lifecycle, as well as to the cost, in energy terms, of constructing—or repairing—that particular building³.

Therefore, looking at architecture from the perspective of time and entropy⁴, the latter introduces two approaches which help us understand the impact of construction on the environment, and which helps articulate a kind of architecture that is subject to change and the workings of chance, as described by Smithson.

Fernández-Galiano links the first approach to the range of atmospheric processes – which from here on shall be referred to as ‘atmospheric weather’ – and focuses his description primarily on energy degradation processes. This approach is seen in architectures which utilise free energies

generated from an efficient use of climate variables as a design tool. Key advocates of this approach are Ábalos and Sentkiewicz's 'thermodynamic materialism'⁵ and Philippe Rahm's 'climatic functionalism'⁶.

The second approach goes back to the range of geological processes – the 'historical time' – and places its focus on the processes of matter degradation. It encompasses, in its multiple variations, all architectures revolving around a "re" premise – restore, rehabilitate, reconfigure – whose *raison-d'être* is to recover the built heritage in one way or another. Different types of works are identified on the basis of the nature of the relationship established with the existing building. While some works reject a harmonious dialogue with the past and impose an overly modern architecture, others carelessly mix new and old, ignoring differences in language and contemporary issues, focusing on preserving, solely and at all costs, that which already exists. Within this broad spectrum there exists a line of action that scrupulously brings both realities together, choosing to 'intervene'⁷ on built heritage from a contemporary standpoint, yet respecting the elements of the past and upholding dialogue over force. An architecture that speaks the language and applies the techniques of its time, but that is able to weave old and new elements together in a balanced, precise and coherent manner⁸.

This article focuses on those works that, in the spirit of minimising the impact of human construction on the environment, are capable of blending both entropic approaches, catering to energy degradation and matter degradation in equal terms, vindicating and hybridising climate (the 'atmospheric weather') and memory (the 'historical time') as design tools for intervention on built heritage⁹.

This line of thought is to a certain extent a review of the "dialectics of entropic change" articulated by Smithson, as it implies viewing construction as a process whereby elements experience changes in an evolutionary sense, both from an atmospheric and a geological point of view, in equal degrees. In simple terms, this approach can be described as an attempt to tackle intervention on built heritage from the principles of thermodynamic design.

To that purpose, we will analyse two contemporary works that paradigmatically represent this approach: Lacaton and Vassal's FRAC Nord-Pas de Calais, in Dunkirk, France, and H Arquitectes' Centre Civic Cristalerías Planell in Catalonia, Spain. The development of both projects, completed in 2013 and 2016, respectively, coincided with the global economic recession brought about by the collapse of Lehman Brothers in 2008. Both share the same starting point – the goal of transforming a former industrial building into new cultural premises. This is not coincidental; as Philip Ursprung pointed out, "deindustrialization has been one of the driving forces for urban change since the second half of the 20th century"¹⁰.

The FRAC Nord-Pas de Calais, located in the once bustling port of Dunkirk, converted an old ship warehouse from the early 20th

century into a new cultural institution, acting as a catalyst for change in its suburban surroundings.

The project revolved around showcasing the original building's features while skilfully responding to the needs of local weather conditions¹¹. It was decided that the best way to preserve and highlight pre-existing features was to keep them as they were. Thus, an adjacent building was projected to stand beside the original as a lookalike, but with its features reinterpreted in line with contemporary techniques, ensuring the functionality and energy efficiency of the new compound.

The Centre Civic Cristalerías Planell, located behind Barcelona's busy Avenida Diagonal, overlooking the Mediterranean Sea¹², tackled the refurbishment and integration of an old glass factory – whose south-east and north-east façades alone were in a good state of preservation – to house new public premises for the neighbourhood.

Preserving the compactness of the primitive building and retaining both its visual power and its function as a catalyst for public activity, the intervention, in line with its urban context, makes full use of the space available, to the extent that both buildings end up blending into each other, old and new fully interwoven. Two courtyards on either side of the building act as 'catch-all' spaces and resolve the premises' intricate triangular floor plan.

The key to success in both works resides in their being two dual, hybrid, harmonious proposals that understand and blend energy and memory as the two primary elements of intervention. Beyond the obvious attention to pre-existing features, these works reveal a fascination for vernacular thermodynamic types and their use as a source of knowledge to meet energy needs and adapt to different weather conditions solely through pure architectural form and passive strategies¹³. Vernacular types are thus understood as an open catalogue of thermodynamic mechanisms available for use wherever their thermodynamic qualities may be required.

To optimally cater to a variable climate in terms of both daily temperatures and seasonality, it is necessary to combine and hybridise a range of strategies with regards to thermodynamic types. When operating in a coordinated way, these can transform a building into a kind of passive thermal super-machine, guaranteeing a high degree of energy efficiency at the lowest possible level of consumption in nearly any situation. Similarly, focus needs to be placed on the pre-existing building, highlighting its best features in terms of energy, materials and space in order to ultimately create a two-way dialogue between elements old and new. This design process will be referred to as the creation of 'heritage thermodynamic systems'.

In both cases under examination, the design of the building enclosures is based on the

integration of passive strategies within their own morphology, seeking to minimise energy consumption through the reinterpretation of the original architecture in line with contemporary thermodynamic techniques.

In the case of FRAC, the adaptation of the original greenhouse in use, form and scale presents flaws similar to those of the original design – excessive exposure to cold, cloudy weather, a tendency for accelerated biological processes, and high sensitivity to humidity changes. It therefore becomes necessary to strip the glasshouse of its specificity.

Consequently, under the large bioclimatic enclosure lies a massive inertial volume that is capable of storing the energy of the air heated by the greenhouse's polycarbonate and Ethylene tetrafluoroethylene (ETFE) enclosure. This element, engaging in a formal and material dialogue with pre-existing features, translates into a large structure of reinforced concrete and fibre cement pre-fabricated panels. When the sun sets, the process is reversed and the heat is then passed on to the air stored within the greenhouse's enclosure, balancing its temperature. A similar process takes place in Halle AP-2's old adjacent structure, whose adjoining façade also becomes a thermal storage battery.

In the summer, a built-in device automatically activates the opening of gaps in the enclosure at the top of the building, as well as alongside the northern façade, enabling the heat to filter out, thanks to the natural ventilation created by the difference in height.

In Cristalerías Planell, the skilful reinterpretation of the solar chimneys, paired with a subtle system of courtyards contributing to formally mirror the original building, helps release all heat stored indoors during Barcelona's trying hot, humid summers. However, this system proves insufficient to meet thermal needs during the winter.

To meet these needs, the new build is conceived as a compact piece of great thermal inertia that gives new life to the original ceramic materials. Due to the glasshouse effect, an appendix on the southern courtyard, made of glass and ETFE, becomes a kind of heat catcher, almost as a way to salute and reminisce about the building's past as a glass factory. While in the summer the ventilation system captures air from the shielded courtyard areas, it can now reconfigure itself to trap the heated air underneath the heat catcher and transport it into the building's interior. Finally, the thermal inertia of the new compound is able to store all the energy redirected through the ventilation system.

Looking at the consumption peaks, both pieces of work have active low-consumption systems based on energy exchanges with the environment. FRAC boasts an aerothermal system based on air-to-air exchange, while Cristalerías Planell opted for a geothermal system with radiant flooring based on earth-to-water exchange. The choice of active system ties back to the final use that each

building was conceived for. In the former, air provides a more immediate solution vis-à-vis a high volume of visitors expected within a short period of time. In the latter, a choice of radiant flooring allows for more progressive heating in response to a prolonged, more consistent use.

It can also be said that the three fundamental elements that define a typical thermodynamic system in architecture (“form-matter-ventilation system”)¹⁴ are, in both of these heritage thermodynamic systems, dually conditioned by the relationship that must exist between the thermodynamic processes governing climate comfort and the dialogue with pre-existing features.

While the form of both compounds revisits the primitive thermodynamic types in response to local weather conditions, it is in both cases altered to force a dialogue with, and bring out the features of, the original buildings. In FRAC, this happens through a process of spectacular mimesis. In Cristalerías Planell, through filling in the gaps of the original volume.

The material nature of both compounds is conceived on the basis of thermodynamic premises, where materials are understood as energy-capturing or energy-storing elements. Once the global thermodynamic needs are established, these are disposed following a pattern that ties the light, transparent industrial technology of the capturing elements back to the spirit of modernity. In turn, storing materials, opaque and solid, form a more direct relationship with the pre-existing features, naturally determined by its inertial condition. At the same time, any storing material required additionally in order to reach thermodynamic balance would be a reminder of the original building’s materiality, establishing a subtle dialogue of continuity that contributes to further blurring the boundaries between old and new. From this angle, FRAC boasts a structure of concrete porticos that replicate the rhythm and materials of the original, while in Cristalerías Planell different types of ceramic bricks pay tribute to the building’s original materiality.

The ventilation system looks to minimise air movement when the need is to store energy, and favours movement when the need is to release it. In FRAC, the air movement system is reduced to the maximum, since the key requirement of the compound is to capture heat. Sunlight is thus maximised to transmit heat to a great mass of air, warming the air pockets sitting between the inertial box and the capturing enclosure. In Cristalerías Planell, where cooling is the main requirement, heat release becomes critical, as does a high ventilation system. To achieve this, solar chimneys suck the air out from the courtyards into an inner ductwork which cools the air as it travels through. Thanks to three natural ventilation systems –Venturi, chimney and glasshouse– these devices suck up the air that controls the building’s temperature with no energy use whatsoever. Following a threefold review of these works from a form, matter and ventilation

standpoint, as well as the analysis of enclosure design and the examination of passive and active strategies applied as a response to the context of each intervention, we propose five common characteristics that define these heritage thermodynamic systems beyond any differences in the materials or techniques used by each to adapt to both pre-existing features and local weather conditions¹⁵.

Air as a project material

Despite its inert nature, air is a project material capable of defining architecture. Sota outlined this in a context where mainstream thinking advocated airtightness and air conditioning efficiency: “Architecture is the air we breathe–now, it is an air loaded with, precisely, architecture”¹⁶. In the two cases we have examined, air becomes a lead character, determining the form of the compound in line with its own movement and acquiring a key role from a material standpoint. The vacuum –which is ultimately the space taken up by air– essentially raises as the realm of dialogue between the old and the new.

Thermal inertia as a heritage piece inherent to original industrial features

Both pieces show the extent to which working on a historical building benefits a kind of architecture conceived under thermodynamic premises, and vice versa. One of the paramount values of these interventions is the use of the original industrial features, as well as their intrinsic inertial materiality, as one additional element of the thermal super-machine that the compound will become. Preserving the existing structure provides an opportunity to benefit from its energy qualities at no cost, from both a consumption and a construction perspective.

The value of interim stages in contemporary projects

A thermodynamic understanding of architecture implies a dialogue with matter and, inevitably, with time and memory. As a result of multiple interventions over time, buildings become a sort of palimpsest where past experiences intertwine with new modern realities. As though we could read from their superimposed strata, as though they were material structures capable of explaining their own transformations.

These works understand architecture as a living discipline resulting from an entropic view of time. They are conceived as open interventions, aware that modern projects are simply part of a process and accepting of their interim condition between a building’s past and a building’s future.

Instability as a condition for balance

These works are characterised by being open systems which find balance within their own instability, and that guarantee their versatility in multiple scenarios. From a thermodynamic standpoint, they are conceived as global organisms in continuous evolution. Within them, indoor comfort does not depend on

machine-conditioned air, nor is it oblivious to outdoor conditions–instead, it is reached through permanent exchanges with the atmospheric environment, in search of thermal balance.

From a functional perspective, the ephemerality of both buildings’ end purpose becomes a programmatic paradigm. Spaces are designed and conditioned so that they can offset certain programmatic instability and house, each within its scale, planned and unplanned activities alike. Finally, from a materials standpoint, tension is generated between old and new, a relationship halfway through mimesis and contrast, whose ultimate goal is to highlight both pre-existing and newly-added features in a juggling exercise between the monumental and figurative scale of the original structure and the abstraction of modern enclosures.

The interim space as a defining trait

The interim space, understood as a place for energy, functionality and materiality mediation, becomes a defining trait. The interim space is the place for everything unstable, uncertain, where exchange occurs. In thermodynamic terms, it is the space where energy exchange takes place, a network of subsystems that function as a large thermal pocket, absorbing heat captured by an outdoor enclosure and passing it on to the adjacent inertial structure, or vice versa, as required by the thermodynamic system. From a functional standpoint, it is a place with large amounts of spatial ambiguity and a boost for the compound’s flexibility. From a material standpoint, it is the place where the tension between old and new is most intensely felt.

Our approach to the interim space is not from a strictly physical dimension. Here it is extrapolated to the social, cultural and historical dimension of everything it represents: a journey towards balance. The Japanese refer to this spatial concept as ‘Ma’: “according to Japanese philosophy, that space would be filled with energy, inducing to a state of contemplation in which it is possible to appreciate the expansion of space and time”¹⁷.

The conclusion to be drawn from the above is that, far from applying standard criteria of intervention on built heritage, primarily based on language, physical context or programme, these restoration works follow design premises that are founded on energy exchanges with the neighbouring environment. These interventions are seen as open to change and variability in terms of both atmospheric weather and historical time.

What is more, both cases in point show how an intervention based on thermodynamic premises introduces section as a key design tool, giving way to a different approach to pre-existing buildings, which are typically only tackled in plan and elevation.

Equally worth mentioning is the focus placed on vernacular architecture as a starting point for both works. Nevertheless, there is an

ambivalence that transcends the typological or the mere restoration of vernacular systems. The interest in new materials and systems capable of offering a more immediate active response than those simply provided by inertia manifests itself clearly and unmistakably in both cases. In Cristalerías Planell this interest translates into its iconic solar chimneys, while FRAC boasts a more homogeneous approach through its large bioclimatic enclosure.

These interventions showcase how it is possible to make the entire system work technically as well as aesthetically, through a process of blending old and new features. From a physical perspective, this is achieved through an exercise of material and spatial contrast between both realities, which brings to light the scars and bonds between the pre-existing and the newly-added. From an intangible point of view, this is achieved by hybridising two models, seemingly opposed in terms of materials but well-assorted from an energy standpoint. In FRAC, the polycarbonate and ETFE enclosure makes sense in conjunction with the concrete structure inside it and the presence of Halle AP-2. In turn, the air sucked up by the solar chimneys in Cristalerías Planell is largely sufficient to condition the building, thanks to the building's outstanding thermal inertia.

As a result, we can appreciate in both works an evident material dualism that reveals the tension created when light technology is used to meet the needs of a hefty building. We can look at each project in the light of multiple dualisms: the massive versus the ethereal, the stable versus the fragile, the opaque versus the transparent, the industrial versus the handcrafted, and so on.

However, although both works represent a new approach to energy and built heritage, two of the most fundamental topics in today's architecture, neither of them is to be considered the epitome of success, but an approximation to it. Despite their significant reduction in energy use, both in terms of daily consumption and through the restoration of historical features, high energy costs still lurk behind the production of materials used for the works, particularly in the case of FRAC.

For this reason, in order to mitigate the impact on the environment, the response must be coordinated and adhered to by the multiple stakeholders participating in construction work. A deeper level of involvement of the industrial sector and further commitment towards the use of less environmentally-damaging production methods are essential. Unless this becomes a reality soon, all technical and architectural efforts to maximise the lifespan and cost of historical buildings will be to no avail.

Still, these works are particularly noteworthy in how they are able to generate memorable images, allegories of "thermodynamics beauty"¹⁸ overlapped with the restoration of built heritage. From a notion of aesthetics based on blending and hybridisation, these architectures seek to resolve the tensions and challenges inherent to the passing of time.

This modus operandi, this way of combining old and new, is precisely what gives birth to something never seen, never heard of, even strange and unknown, yet beautiful—like Mary Shelly's Frankenstein. And beyond any first impression of contemporary hybridity, the allure of these works ultimately resides in their enduring nature despite the passing of time, in their conversion to a new concept of luxury and comfort based on environmental wellbeing and the value of reutilisation. In the exercise of enjoying life resides the beauty of this 'new-old' architecture.

In this sense, we could almost state that the ultimate purpose of these works is to bring to light the notions of time and change, those invisible materials on which both architecture and life are built. Something that ultimately can be construed as a direct consequence of viewing architecture as Smithson's "dialectics of entropic change" referred to earlier on.

These works are capable of materialising the ever-changing weather conditions as built form and matter that negotiate energy fluxes just as they control gravity. They seek to reveal the fate of historical time, through a subtle, graceful blending of the different stages of history and memory created by architecture, overlapping past and present, and opening a window towards the future, for no architecture project is closed and finite, but the reflection of an interim stage.

1. Robert Smithson, "Entropy made visible", in *Robert Smithson: The Collected Writings*, ed. Jack Flam (Berkeley/Los Angeles/London: University of California, 1996), 301-309 (Author's translation).
2. The following definitions are included for context: - Thermodynamics: "The area of physics connected with the action of heat and other types of energy, and the relationship between them", Cambridge Dictionary, "Thermodynamics", accessed November 2020, <https://dictionary.cambridge.org/>. - Entropy (Thermodynamics): "A measure of the unavailable energy in a closed thermodynamic system that is also usually considered to be a measure of the system's disorder, that is a property of the system's state, and that varies directly with any reversible change in heat in the system and inversely with the temperature of the system". Merriam Webster Dictionary, "Entropy", accessed November 2020, <https://www.merriam-webster.com/>.
3. Luis Fernández-Galiano, *El fuego y la memoria* (Madrid: Alianza Forma, 1991), 123-128. AN: The Spanish author articulates the architectural implications of the various notions deriving from the concept of entropy inherent to the second law of thermodynamics; from Ilya Prigogine's "entropic optimism", which results in a more passive architecture, primarily concerned about control rather than maximising the use of natural energies—ultimately, the architecture of sun and wind—to Nicholas Georgescu-Roegen's entropic pessimism, which translates into an architecture focused in the restoration of built heritage.
4. Luis Fernández-Galiano, *El fuego y la memoria* (Madrid: Alianza Forma, 1991), 69. "Entropy modifies the conception of time in a two-fold manner: it introduces a course of direction while establishing its own rhythm. Because it associates time to fate, to events, to irreversible changes, entropy governs the sense of time: that in which entropy augments." (Author's translation)
5. Iñaki Ábalos & Renata Sentkiewicz, *Ensayos sobre termodinámica, arquitectura y belleza* (Barcelona: Actar, 2015).
6. Philippe Rahm, "La forme et la fonction suivent le climat" in *Environ(ne)ment. Manières d'agir pour demain / Approches for tomorrow*, ed. Giovanna Borasi (Montreal: Canadian Centre for Architecture 2006), 128-137.
7. Andrés Cánovas, "Después de la industria" in *Arquitectura Viva* 148, "Transformaciones" (2013), 20-21. "[...] the intervention stems from the question, sometimes impertinent, about the quality of things; it mulls over the necessity and, ultimately, concludes what it has to do in a brave, crude manner." (Author's translation)
8. As examples of this concept of intervention, we could cite works such as the Biblioteca de las Escuelas Pías by Jose Ignacio Linazasoro; the Hotel Atrio by Tuñón y Mansilla; the Parador de Alcalá de Henares by Aranguren & Gallegos; and Medialab Prado by Langarita & Navarro, among many others.
9. In a valuable exercise of collective exploration, an incipient school of architects that draw from affinities and shared interests in climate and built heritage are working along these lines. Amongst others, we can cite some of the works by Marcos Casagrande, Gion Caminada, Assamble Studio, Eñeres, Ábalos + Sentkiewicz, Roldán-Berengué, Lacaton & Vassal and H Arquitectes.
10. Philip Ursprung, "Aires de cambio. Un viaje por los edificios de H Arquitectes" in *El Croquis* 203, "H Arquitectes" (2020), 326.
11. Dunkirk, a region in northwest France bathed by the English Channel, enjoys a mild climate all year long—Oceanic type (Cfb) according to Köppen-Geige's climate classification. There is a predominance of long cold winters, typically full of wind and rain, whereas summers are typically mild and comfortable, although

rains are fairly intense even in the drier months. The physical context of the building is worth pointing out here, as it is located in open land, utterly exposed to inclement weather.

12. The city of Barcelona, located on the Mediterranean shores, in the northeast of the Iberian Peninsula, boasts warm and mild temperatures all year long—Mediterranean type (Csa) according to Köppen-Geige's climate classification. Summers are of medium duration, hot, humid and primarily sunny, while winters are slightly longer, fairly cold and partly cloudy. The building is located in a well-established district within the city centre, which warrants certain protection against poor weather (e.g., less exposure to the sun in lower areas due to shadows cast by neighbouring buildings, currents of air, etc.).

13. Climate or thermodynamic types are spatial and material concatenations adapted to each climate habitat whose end goal is to generate comfortable spaces—environments that can ultimately boost the feeling of wellbeing in the human body. There is a climate type specific to each habitat and, within it, we would find different subtypes in line with how those spatial and material concatenations defining climate types are configured. A few examples of these are igloos, mountain houses, typical patio-houses in Seville and traditional house buildings in Cairo.

14. Iñaki Ábalos & Renata Sentkiewicz, "Materialismo termodinámico", in *Ensayos sobre termodinámica, arquitectura y belleza* (Barcelona: Actar, 2015), 243-261.

15. Ultimately, these works show two different sides of one philosophy. While the former caters to typically Central European cold weather (Cfb-Oceanic), the latter adapts to the milder southern climate (Csa-Mediterranean). This goes to show that thermodynamics as a design tool is a kaleidoscopic phenomenon, one of many faces, although it is founded on common principles irrespective of climate conditions.

16. Alejandro de la Sota, As cited in: Iñaki Ábalos, *La Buena vida. Visita guiada a las casas de la modernidad* (Barcelona: Gustavo Gili, 2000), 179.

17. Tomie Hahn, *Sensational Knowledge: Embodying Culture through Japanese Dance* (Connecticut: Wesleyan University Press, 2007), 53. "Ma is a Japanese term that could be translated as pause, space, gap or interval. It isn't just a void or absence of content—it is a conscious space, a breath that lends itself to highlighting the other parts of the work, even creating new meaning. According to Japanese philosophy, that space is filled with energy and could induce a contemplative state in which it is possible to appreciate the expansion of space and time". (Author's translation)

18. Iñaki Ábalos & Renata Sentkiewicz, "Materialismo termodinámico", in *Ensayos sobre termodinámica, arquitectura y belleza* (Barcelona: Actar, 2015), 260-261.

"Thermodynamic beauty does not access any stability or canon, it stems from the combination of new parametric ways of calibrating matter with the imperfection of the ordinary and the programmatic, from a subjective aspiration to see buildings and towns resemble and breathe like the people that live in them, and reflect their best wishes. The hypothesis of thermodynamic beauty is based on the assumption that culture and knowledge make the human species achieve moments of order within chaos." (Author's translation).

Thermodynamics Heritage Energy Memory Intervention