Studio Anne Holtrop

ETH Zürich

design studio

FS24

MATERIAL GESTURE:

HEAT

TO BOIL

TO MELT

TO BURN

TO DRY / HARDEN

TO CORRODE

PURIFICATION

REFUGE

COMFORT

DANGER

RITUAL

Richard Serra, SCULPTURE in production, 2022.

CONTENTS

“Fire has no precise consistency, but its presence can actively transform matter into different states. ... Out of a river of fire, all manner of shapes later materialize and solidify.”

— Josep Lluis Mateo

MATERIAL GESTURE:

HEAT

Time does not exist, according to British physicist Julian Barbour. He argues that we have no evidence of the past other than our memory of it, and no evidence of the future other than our belief in it. “Difference merely creates an illusion of time, with each individual moment existing in its own right, complete and whole.”

What we notice as variations in shape, or changes in the position of objects in our surroundings gives us an illusion of time, but according to Barbour’s theory, they are simply differences between states of matter.

For all matter on earth, it is not time that changes its state, it is heat that creates different states of matter. The earth is a geologically active planet

and can be seen as a hot body immersed in a cold space, with a continuous loss of temperature. Active volcanoes with lava eruptions or geysers and hot springs are the most perceivable and mesmerising examples of the heat stored deep in the earth and its effect on matter. It made the famous volcanologists Maurice and Katia Kraft go each time closer to bursting volcanoes until it ultimately took their lives by an eruption in Japan.

Rock is always being formed by heat, worn down into pieces, and then formed again. This is called the rock cycle. Rock wears down through erosion, then settles and slowly becomes sedimentary rock. If that rock becomes deeply buried, it may melt by the earth's internal heat into magma. Then the magma may return to the surface as igneous rock. The rock cycle is a materialisation of time over many millions of years, and it is almost abstract.

We can witness the use of heat and the altering of matter in most places of production. For the production of our materials, such as the smelting of alumina (derived from bauxite ore) to extract pure aluminium, or for the production of cement out of limestone and clay. Foundries use heat to melt and cast glass, bronze, brass, steel, and aluminium. And heat is used to form and alter the shape of materials, such as blowing glass, or the tempering of

it. For who have visited these places of production know it is truly impressive and magical to see matter altered under these extreme heat conditions. With enough heat, rock will melt in front of your eyes.

The most important invention in human history is fire. Without fire, humans could not have changed their diet, warmed their places, protected themselves, and produced more advanced tools. The central presence of fire, the hearth, is central to many cultures. Considered as sacred many traditions grew out of these early worship rites. Fire gods were, and still are in certain cultures, worshipped and celebrated. In India, the fire god Agni is present in major rituals such as weddings and cremations. The Irish Celts worshipped Bel to whom they lit great bonfires each May Day, also known as Beltane Eve.

Much more recently, Peter Zumthor used fire to create an intrinsic space for reflection with the Bruder Klaus Field Chapel. For him the question was which tools to use to make a sacred space, a space for devotion, that is not based on liturgy. In his words: "water and fire, matter and transcendence." To achieve this, Zumthor used a smouldering fire to burn the inner wooden formwork, which in turn left all of its traces on the concrete.

In this semester we will explore how we can use heat in the production and formation of matter, and possibly how traces left during the formation of matter by heat can remain visible in its end state.

You will be asked to make a sacred space. What can a space of devotion be nowadays? How do we find meaning and beauty in such a space? And how is heat, one of our most essential conditions, made present in the formation of that space?

Anne Holtrop

DESIGN STUDIO

When we take all aspects of the material into consideration – the geology, the sourcing, the industry, the different properties, the craftsmanship, the specialised techniques and the cultural significance – we can deploy the full potential of the inherent qualities of the material itself and our way of working it in what we call MATERIAL GESTURE.

In this design studio, you will define your gestures of making and working with material(s) through research and experiment, and in response to the topic of the studio. You are required to produce an architecture that results from your specific engagement with the material and the spatial condition you construct with it. The architecture that results from this approach does not reference or represent something, but simply attempts to exist as a physical spatial reality in its own right.

Your research should be supported by the knowledge made available by our studio, and engaged through you with the use of available resources and facilities at departments of the ETH and from external specialists / fabricators.

Throughout the whole semester, and for your final presentation, we require that you work with physical (fragment) models of your building in the actual material(s). It is important, in this design studio, not to make a complete building, but to show and support the found values of the material engagement in a spatial way, based on the full potential of the inherent qualities of the material itself and your way of working it.

ASSIGNMENT

In this studio, we work in a workshop and laboratory-like setting where you research, design and test the proposed material. The material and the ways of making are not a presentation outcome of the design studio but rather, an integral part of a process of working, researching and designing.

There is no given program for the space. This can be chosen at any time in the development of your project and should support the spatial and material conditions that you have set out.

For the final presentation, you are required to make a physical model of your work, or a fragment of it, in a scale of 1:15. The model should show the material and the gestures (the ways of making) and the specific spatial conditions it constructs. This is the key element of your presentation, along

with samples of the material research and test models. You are required to display the material gesture research, drawings of the project and photos of the model alongside your model on portrait A2 sheets.

The A2 material will be collected in print and digitally in PDF format for the material gesture archive. A semester result book will be made after the presentation. From a selection of a maximum of three projects, the models and material research will be crated and archived for future exhibitions.

SCHEDULE DESIGN STUDIO FS24

INTRODUCTION
Feb 20 & 21

On the first day, the team will give an introduction to MATERIAL GESTURE and the specific topics of this design studio, Heat. Members of the team and experts will give lectures and at the end of the session, you will choose the fields you want to engage with and make groups based on affinities of your shared interests. We will introduce how we work within the studio; we aim that you learn that model, image and drawing are tools to develop your project.

STUDIO WEEK 2
Feb 27 & 28
Research topic
(with Anne Holtrop and DS assistants: Yuiko, Arturo and Philip)

Experiments with the material and ways of making. You are required to present the research topic of your interest through material tests and research, following your personal interest on heat. To understand the idea of material gesture, you will be modeling, sketching and working together with Anne.

FIRST TABLE REVIEW **Mar 5 & 6** **Gesture of heat in relation to matter (with DS assistants)**	**You will present your research and first experiments. In this review, your material research will be discussed, and you will have to present the sources and the specialists/ ETH departments involved that are essential for your research. The material research and experiments are documented through photography, material samples, writing, and drawing.**
STUDIO WEEK 4 **Mar 12 & 13** **Spatial translation of research (with Anne Holtrop and DS assistants)**	**You will find a way to translate your reseach, material gestures and experiments into the best suitable spatial configuration. Some first translation into the architectural context should be made and relate to the material engagement.**
SEMINAR WEEK **Mar 18–22**	
STUDIO WEEK 6 **Mar 26 & 27** **Project development (with Anne Holtrop and DS assistants)**	**We will continue our discussion of the previous reviews and aspects of your work together in depth on your project.**
STUDIO WEEK 7 **Apr 1–7**	**Easter holidays**

STUDIO WEEK 8
Apr 9 & 10
Spatial condition, gesture and research
(with DS assistants)

You will be required to present your research and your architectural spaces that are consequential to your material interest and fully exploits the material gesture in a spatial way. We will discuss architectural articulation and cultural significance in relation to material research and ways of making.

MID-TERM REVIEW
Apr 16 & 17
Spatial condition, gesture and research
(with Anne Holtrop, guests and all studio assistants)

It is important to understand your research and ambitions of your project as well as the constrains and conditions you work with and what possibilities they offer. You will be required to present your projects through architectural drawings – floor plans and sections – and first more detailed construction drawings. You will be evaluated on the development of the previous table reviews (gestures and space) under the categories of research, conceptual approach, material development and presentation.

STUDIO WEEK 10
Apr 23 & 24
Ways of making space

In this week, we will elaborate more in depth the construction techniques and applications that you will develop out of your material research and their spatial consequences. We will use the constraints and problems of translating your project into reality as tool to find specific solutions for developing your project's narrative. Therefore, we will successively increase the scales of model making and drawing.

STUDIO WEEK 11 **Apr 30** **Ways of making space** **(with Stephan as a guest assistant for further inputs)**	
May 1	**Holiday**
STUDIO WEEK 12 **May 7 & 8** **Gesture, space and structure** **(with Anne Holtrop, Mario Monotti and DS assistants)**	**Together we will discuss the relevance of structure and the ways of making in relation to your project.**
STUDIO WEEK 13 **May 14 & 15** **Detailed project discussion** **(with DS assistants and Stephan)**	**We will continue our discussion of the previous reviews and aspects of your work together with the ways of making and final model, drawings and photographies, which as tools become strongly representative of what your project is about.**
STUDIO WEEK 14 **May 21 & 22** **Pre-final presentation** **(with DS assistants and Stephan)**	**Your project should be in an almost final state and we will discuss mainly how to present your work at the final review.**
FINAL PRESENTATION **May 28** **(with Anne Holtrop, assistants and guests)**	**You will work on the final presentation with an exhibition of the final models, material samples and A2 drawings and photos.**

TOOLS

In our design studio, we stress working on models, drawings, and photography as tools to develop projects. The three should link and grow together.

Model as Tool

The purpose of model-making is to study different conditions. The study will be constantly worked on on a weekly basis for different focuses such as material tests, the context of the project, volume, structure principles, materiality, atmospheric or spatial conditions, etc throughout the semester. It means you will experience different types of models. The scales and materials of the models can vary depending on the focus.

Drawing as Tool

Through the act of drawing, we can explore the physical process of making in an analytical sense and synthesise key aspects of a project. Together we will explore the different scales and methods of drawing, from surface textures that change over time to the constructive assembly of different elements, from the

illustration of experiment arrangements to the communication of technical details.

Photograph (Video) as Tool

An important tool of narration to communicate project intentions and research: it questions how we talk about things. Photography becomes an important part of the narrative that helps to explain the project once we have site visits, experiments, material tests, and model studies. It becomes a way of focusing, of editing, of looking, of putting work in relationships. It is important to think about the print and check how your photography narrates your intention clearly. With video, we can also include the aspect of time in photography. Together with drawings, are tools to analyse and annotate what we are doing, it is essential to document what we do.

VISUAL ESSAY

HEAT

An installation within London's annual MERGE festival. British artist Alex Chinnek conceived a full-scale, two-story building constructed entirely from 8,000 wax red bricks, designed to gradually melt over the course of a month. As the days progressed, the structure transformed, leaving behind only its roof and foundation in a pool of molten wax.

Alex Chinnek, A POUND OF FLESH FOR 50P / MELTING HOUSE, London, 2014.

GG: All these issues of nature, of body, of line, of balance, come out to me in the Splash Pieces (1968–70), which are a perfect distillation of these things.
RS: Splash Piece: Casting is definitely about drawing and line: I'm using the juncture of floor and wall to cast a sharp edge, a right angle. That angle then disappears as I build up the cast with molten lead, but the cleavage of the sharply drawn edge reappears as the cast is pulled away from the juncture of wall and floor and turned over.

Excerpt from a conversation between Gary Garrels and Richard Serra, published in: Rose, Bernice, et al. Richard Serra Drawing: A Retrospective. Menil Collection, 2011.

Richard Serra, throwing molten lead from a ladle to create one of his

site-specific SPLASH PIECES, 1970.

The movie Over Your Cities Will Grow is a portrait of the artist at work, though one that says as much about its British director, Sophie Fiennes, as about its stated subject, the German-born artist Anselm Kiefer. Perhaps the most celebrated and divisive artist of his generation, Kiefer was born in 1945 shortly before the end of World War II. In 1993, he moved to a swathe of land outside Barjac, a town in the South of France. He and his assistants then began creating installations on the property that, at least to judge from this movie, are a monument to the human will to self-annihilation and a reharsal for the apocalypse.

On this parcel of land that takes up more than 85 acres and was once the site of an old silk factory, Kiefer and his team burrowed into the earth, dug tunnels, constructed an amphitheatre, painted and threw dust and broken glass on canvases and kiln-fired lead sculptures that look like books, turning the sprawl into a massive atelier that Kiefer called La Ribaute. Fiennes, whose movies include the nonfiction romp The Pervert's Guide to Cinema featuring the loquacious philosopher and cinephile Slavoj Zizek, arrived in La Ribaute shortly before Kiefer moved to Paris, where he now lives and works. The movie offers the only chance that most of us will probably have to visit what he left behind, this strange, eerie Kieferland.

Anselm Kiefer, OVER YOUR CITIES GRASS WILL GROW, film by Sophie Fiennes,

2010.

Yang
Hot and Light

Yin
Cold and Dark

It can be argued that the Yin and Yang concept is the most fundamental idea in Chinese Culture. Ying and Yang are oposing forces. Yang is expanding, hot, light, and moving; Yin is contracting, cold, dark and static. There's no moral connotation to them, there is no good or bad force, they are just like fire and water or like day and night. Just as there's no day without night, and no shadow without light, there can be no Yin without Yang and vice-versa. It is impossible to separate them: if you were to break down a pair of yin and yang things, two new pairs would appear.

Morning scene which the moisture that had been lodged in the thatch due to the difference in temperature between day and night evaporates. This heat of evaporation lowers the interior temperature. In traditional houses built with wood, earth and grass, this evaporative effect has been used to adjust the humidity unique to Japan's climate. Indoor heat and smoke also dissipate through thatched-roof in the same way.

Water vapour rising from Kayabuki-yane thatched-roofs, Japan.

Photo Yukio Futago.

A traditional smoke sauna in Finland.

See reader page 147 for a description of the sauna traditions in Finland.

Joseph Beuys, BURNT DOOR, BEAK AND RABBIT EARS, 1953.

Museum of Modern Art, Vienna.


EPAL

This work comprises of more than 27 tons of black casting sand pressed into an array of daunting, irregular monoliths. Some feature channels doused with molten aluminum, some bearing lava-like swellings.

Raphael Hefti, THE SUN IS THE TONGUE, THE SHADOW IS THE LANGUAGE, 2020.

Kunsthalle, Basel. Aluminium, recycled casting sand.

The forms are crafted from cast glass, to produce the works, Horn poured delicately coloured molten glass into a mould. The liquid-hot glass assumed the mould's shape and qualities as it gradually annealed over the course of three to four months.

Roni Horn, WATER DOUBLE V. 3, 2013–15, New York.

A thermal cutting is performed by melting a metal with a compound gas of acetylene gas and oxygen and cutting it by spraying high-pressure oxygen on it. 1380°C is the melting point for iron. It takes about two hours to cut an 11-metre-long iron bar (d. 6 cm) from one end to the other. For the duration of the process, the artist is required to hold the nozzle of the thermal cutter in midair several millimetres above the iron surface and proceed slowly along the 11,000 mm, or, in this case, 17,500 mm. One can easily imagine that this would be a procedure accompanying highly extraordinary physicality and time and space sensations. Subtle changes in the speed at which the thermal cutting proceeds or changes in the artist's bodily condition are vividly reflected in the expression of the iron once it has been melted and congealed. The iron bar curves substantially in the direction in which the heat radiates towards the cosmos. This is where we witness the physiology of the iron, in which no artificiality whatsoever can intervene. Thermal cutting and welding have been the most basic methods in Muraoka's works since the mid-1950s. However, Thermal Cutting 6000 mm × 1380°C, which Muraoka exhibited at his solo exhibition at Shinanobashi Gallery in 1983, was the first case in which the act of performing a thermal cutting became self-purposeful and was turned into a work. Although they are on the very border of whether they can be called 'oeuvres', Muraoka has repeated this un-compensatory act several times since, proving that it still has an infinite significance for him. What is more, the artist himself (and we the viewers) still have not been able to identify the solution to the mysterious formula "length of iron × melting point of iron."

Saburo Muraoka, NO 20. THERMAL CUTTING: 17,500 MM × 1380°C, 1995.

The Hawaiian term pahoehoe means smooth lava in its solid state, and it entails the most abstract and visually explicit manifestation of the Earth's core's material reaction in the face of a sudden contrast in temperature. When the recent eruption of the Kilauea Volcano happened in the spring of 2018, I vis-ited the Big Island in Hawaii to experience on a scale of 1:1 the Earth turning inside out. Escorted by the US military along with a group of scientists, we vis-ited Ground Zero of the eruption. This was an experience that was impossible to translate into images. As the lava activity subsided, I spent the following weeks walking through the Kalapana Estate areas to experience the contradiction be-tween flowing lava matter and its crystallisation into solid state. Pahoehoe is matter's most spontaneous expression and the most im-mediate visualisation of the chemical reactions that comprise it. The character-istic behaviour of lava illustrates, at both micro and macro levels, processes that pertain to fields like meteorology, linguistics, economics, and genetics, where properties that are equally creative and destructive are made visible. When pa-hoehoe finally cools and crystallises, it displays a strange quality of frozen time. As the philosopher Reza Negarestani says, lava makes evident 'decomposition as a constructive process.' The simultaneous destruction and creation of territory in Hawaii and its repetitive pattern reveal the grammatology of our planet and how the surface of this system that we inhabit is coded.

Carlos Irijalba, PAHOEHOE.

The core of my work is human – time and space – scale and its relation to the world using phenomena that precede it as well as the objects and situations generated by it. For this purpose, I use geological and industrial crafts to unveil our surrounding. This line of work deals with equilibrium and tension from regions with a rich biosphere but also populated and intervened by humans. For Pannotia, I have been studying the relation between landscapes before and after the anthropic in these regions and focused between the Precambrian and the Cambrian periods, 540 million years ago, where the biggest known explosion of life on Earth took place. During that time, most of the Earth was oceanic soil and new land emerged as a type of broom, sweeping millions of species now present on the land as sedimentary and metamorphic rocks. The coast acted as a sort of spatula compressing time and its sediments, as many geological signs show today. It was in that moment that most of taxonomic and vertebrate groups we know today appeared. The next largest transformation has been happening since the first half of twentieth century with the intervention of humans, transformation of landscape, emissions and residue. In my practice, I operate between these parameters of time scale, perspective and recent history to unveil the geological and anthropic layers of each location. In conversation with national geological centres and the local communities, I try to open a dialogue, reading geotechnical drillings to explain the territory and its material legacy. It is vital that, through art, we filter and nourish our relationship with the soil we live on. This turns into a conversation, an exchange of information from the technical to popular knowledge, involving geologists, geographers, philosophers and artists in conjunction with the inhabitants of the area to construct new narratives of stratification and consciousness about our footprint on Earth.

Carlos Irijalba, PANNOTIA.

THE VOLCANO WATCHERS, 1987, episode of PBS Nature featuring the late French Volcanologists Maurice and Katia Krafft. Segments include the Krafft's first research trips to Stromboli, Mt. Volcano, the 1973 eruption of Eldfell on Heimaey, Iceland, and further trips to the Hawaiian Islands, Africa, Indonesia and Japan.

Armin Linke, KAWAH IJEN VOLCANO, Biau (Jawa Timur), Indonesia, 2016.

WILDFIRES. The photo provided by the Santa Barbara County Fire Department,

California, Saturday, Dec. 16, 2017.
48

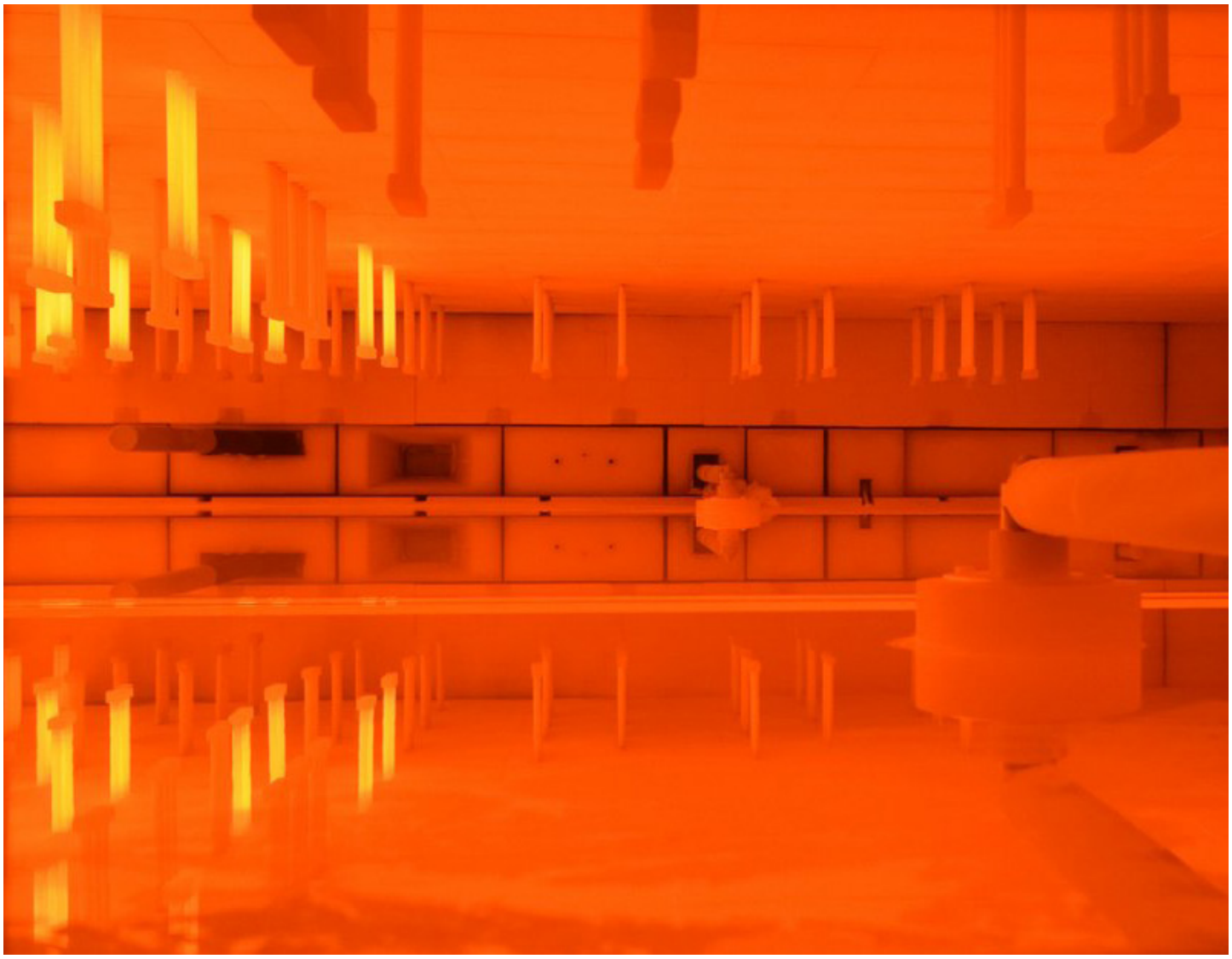


Image of the inside of a FLOAT GLASS FURNACE.

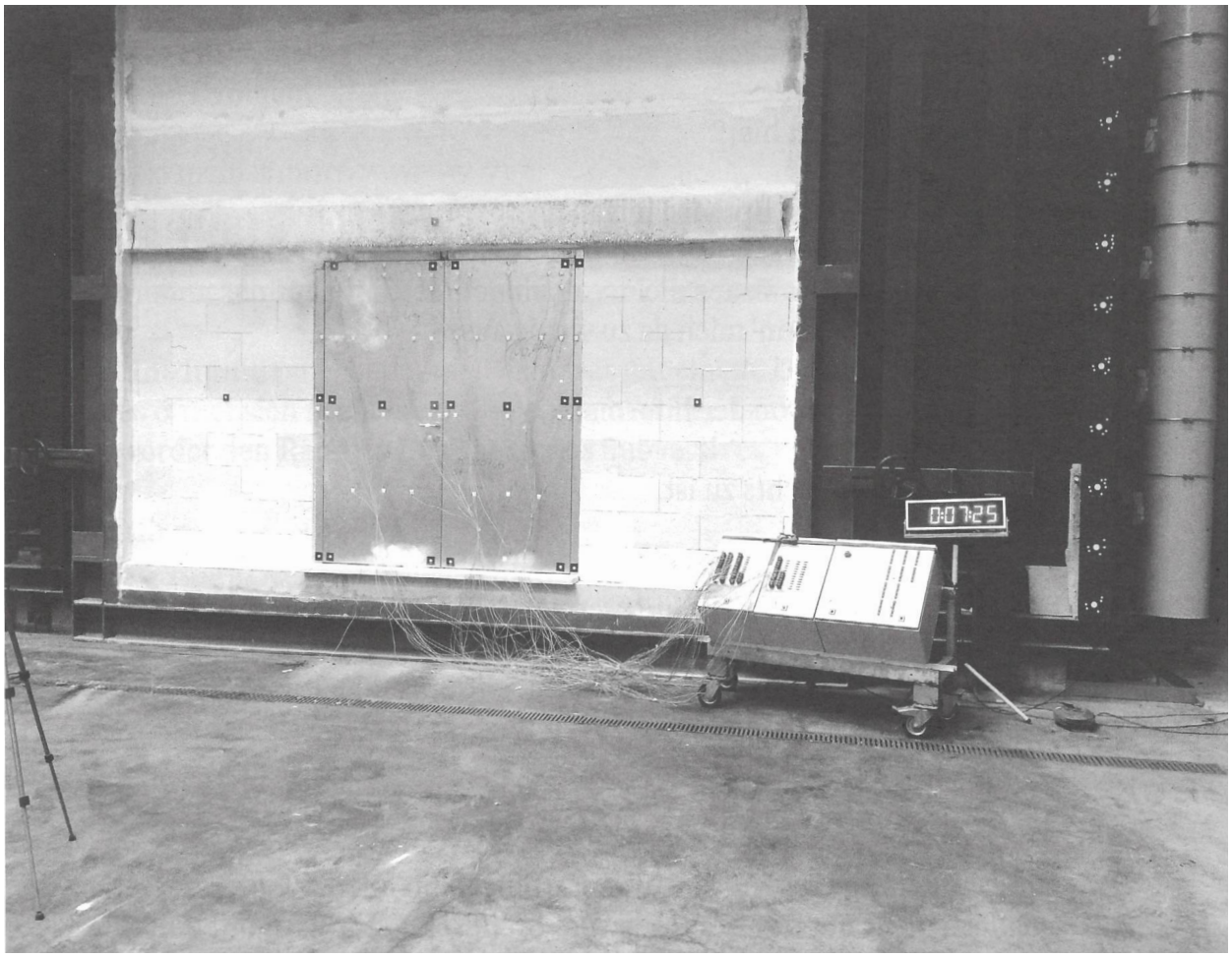
Bitumen is a sticky, black, semi-solid form of petroleum. Deformation properties and fatigue performance are strong characteristics of bitumen material, meaning that over time the material will deform by itself, such gestures are displayed in these works by Bijoy Jain.
Bitumen is mainly used as the liquid binder that holds asphalt together for roadworks. A bitumen-sealed road has a layer of bitumen covered with an aggregate. This is then repeated to give a two-coat seal. Asphalt is produced in a plant that heats, dries and mixes aggregate, bitumen and sand into a composite mix, it is then applied through a paving machine on site, with heat, as a solid material at a required thickness, relative to the final use.

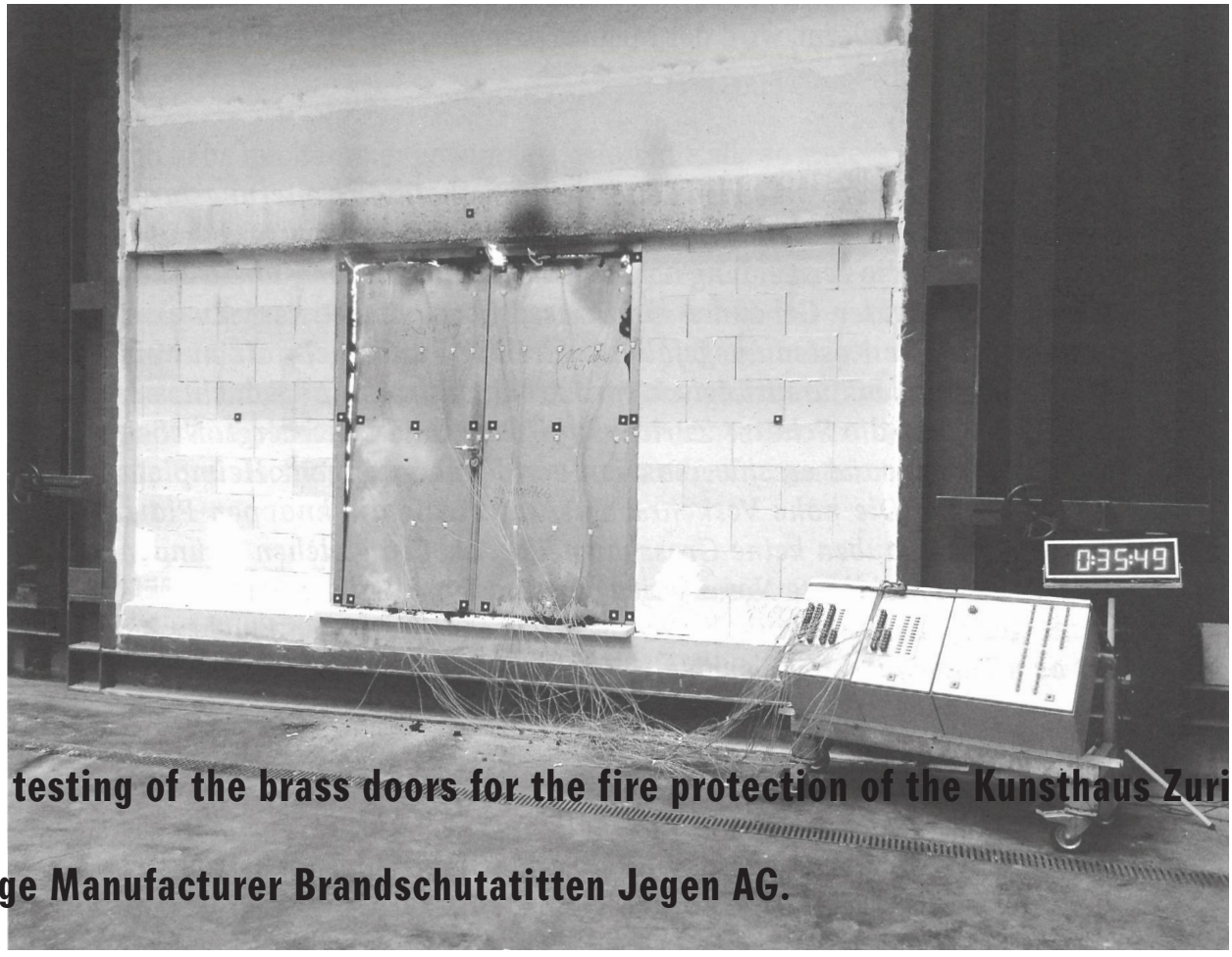
Regulating the heat levels allows for the controlled carbonisation of the cedar surface, leading to charring in specific areas of the structure. During the burning process, the wooden framework, extending across the garden, adapts its shape flexibly to navigate around the mature trees present in the established garden. The result is a pitch-black structure, charred by the flames, evoking the appearance of a weathered ruin.

Junya Ishigami & Associates, KOKAGE-GUMO PAVILION, 2021.

Aerogel is an ultralight nanoporous material. A gel in which the liquid element is replaced with gas. The translucent, extremely low-density substance has the lowest-known heat conductivity in a solid, it is currently being used as insulation in space exploration.

Armin Linke, NASA JET PROPULSION LABORATORY, Pasadena, USA, 1999.





Fire testing of the brass doors for the fire protection of the Kunsthaus Zurich.

Image Manufacturer Brandschutatitten Jegen AG.

Hiroshi Sugimoto, NOH SUCH THING AS TIME, PERFORMANCE, The Kunsthaus

Bregenz, Bregenz, 2001.
57

This documentary explores the legacy of French volcanologists Katia and Maurice Krafft, who were killed by an eruption in Japan in 1991. These images, on the left, show the aftermath of the eruption of Eldfell, in 1973 in Heimaey, Westman Islands / Vestmannaeyjar, Iceland. After the eruption, the islanders used heat from the cooling lava flows to provide hot water and to generate electricity. They also used some of the extensive tephra, fall-out of airborne volcanic material, to extend the runway at the island's small airport and as landfill on which 200 new houses were built.

Werner Herzog, THE FIRE WITHIN: A REQUIEM FOR KATIA AND MAURICE

KRAFFT, Film.

“Two figures are approaching an oil well. One of them holds a lighted torch. What are they up to? Are they going to rekindle the blaze? Has life without fire become unbearable for them?... Others, seized by madness, follow suit. Now they are content. Now there is something to extinguish again.”
Film narration by Werner Herzog.

Werner Herzog, LESSONS OF DARKNESS, 1992, film.

The Hindu festival Holika Dahan is celebrated with bonfires and the ceremonial burning of the demoness Holika. This is a ritual burning of what is dry and dirty in order to pave way for new life in the Spring.

HOLIKA DAHAN FESTIVAL, India.

Mylar blankets are made mostly from a strong and thin plastic called polyethylene terephthalate, or mylar. The mylar is then coated with an extremely thin layer of vaporised aluminium. What results is a thin and flexible material that reflects most of the heat exposed to it. Commonly used by hikers, outdoor athletes, surgeons and first aid responders to keep the wearer warm in specific situations. They work by reflecting the wearers body heat, trapping it inside the blanket.

MYLAR / THERMAL BLANKETS, in this image it is used to cover the Cassini

Spacecraft as protection from the extreme hot and cold of deep space.

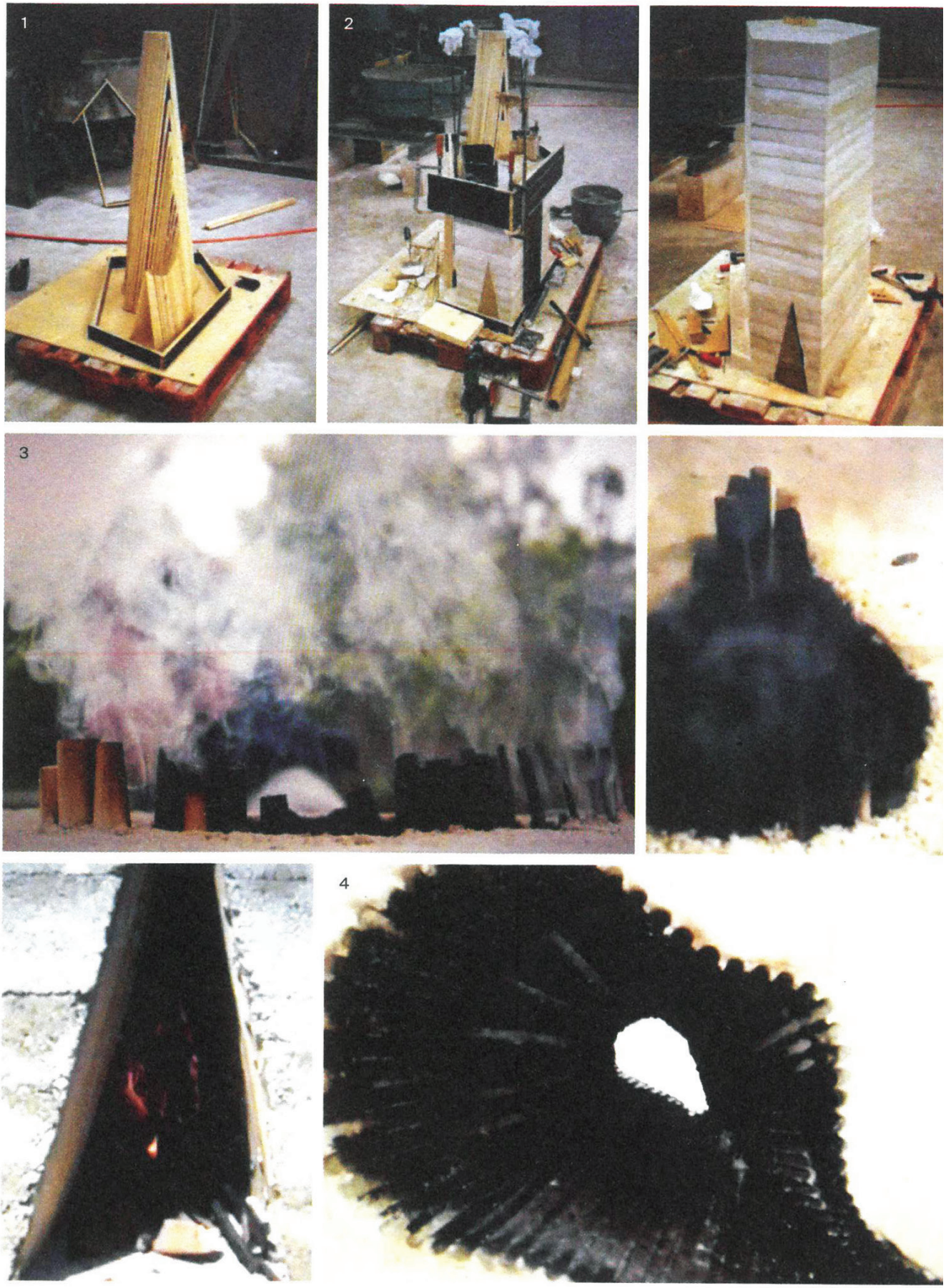
Wind towers are traditional architectural structures found in Middle Eastern countries, particularly in Iran. In essence, a wind tower is a tall, chimney-like tower with multiple openings at the top. As wind flows over the tower, it creates a negative pressure inside, drawing hot air out of the building and replacing it with cooler, fresher air. This passive cooling method has been used for centuries and is still relevant today, especially in areas with limited access to electricity or air conditioning.

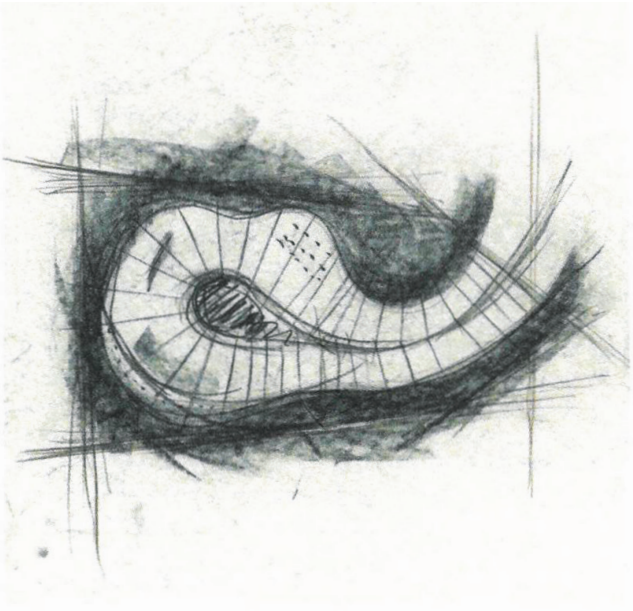
WIND TOWERS, Iran.

Fischli and Weiss, THE WAY THINGS GO, video, 1987.

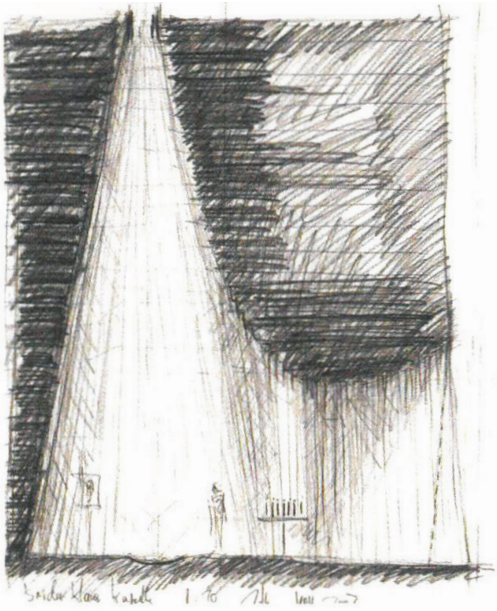
Peter Zumthor, BRUDER KLAUS FIELD CHAPEL, Germany, 2007.
69

Remodelling of the *construction sequence*:
1. Placement of 112 fir trunks from the client's woods to form a large wooden tent
2. 24 layers, 50 cm thick, of tamped concrete are poured over the exterior
3. The trunks are set alight in a slow smouldering fire lasting three weeks
4. The fire shrinks the trunks and leaves a blackened interior. Once the fire is dead, the burnt trunks are removed, while the wooden imprints and the fire's smell remain.
Courtesy: Joseph Valia, Paola Oberto, Elisa Canalis and Enrique Alonso; Erasmus students at the Eindhoven University of Technology, 2011





Ground floor



Section

Some years ago, when I was still a professor, I set an exercise with the title: "Make it typical, then it will become special." This might at first sound like a contradiction, but it is actually my working philosophy: I tackle and attempt to capture the essentials of a task.

The choice of the chapel's location near Wachendorf in Germany was not a difficult one: a beautiful hilly landscape is traversed by woods and meadows that form a kind of grand puzzle. There is no dominant building; just this landscape. It is like the famous bridge in Martin Heidegger's ideal landscape, where he describes the landscape with a river, then somebody builds a bridge across the river, and suddenly the bridge defines left and right, above and below. To some extent, this was also our stance at the beginning.

It required great effort to define something that could be a small room for devotion or reflection in a field. Something which, despite its smallness, would not be claustrophobic; something small that would not look like a miniature of something else. The outer form was not so difficult – a vertical volume with a pentagonal floor plan in a horizontal landscape. The most difficult thing was the interior. The aim was not to design a liturgical room where a mass could be celebrated, but a chapel with a room for devotion.

With time, the design became clear and elemental: light and shadow, water and fire, matter and transcendence; below the earth, above the free sky.

We spent a long time investigating fire. First, we talked to specialists about the smell, since there are some very repellent soot scents, as well as quite lovely ones. Secondly, we needed to clarify how we could burn tree trunks without the heat making the rest explode; the structure could not just be set ablaze. Lastly, how do you burn logs so that a piceous black remains on the walls? I received most help from my local chimneysweep. When I told him what we wanted, he said we needed a very badly smouldering fire – what charcoal burners call a *Mottfeuer* – with low temperatures that immediately produce condensate because the smoke's temperature is so low. These are things you have to learn; they are not written in books.

Peter Zumthor

Transcribed and translated from the broadcast "Spiritual Spaces", *Arte TV*, 13 October 2013; Source: *ZDF*, 2011. Additional information in Peter Zumthor, "Körper und Bild", in *Zwischen Bild und Realität* (Zurich: gta Verlag, 2006); Peter Zumthor, "3 Bauten 5 Projekte", in *Das Haus* (Zurich: gta Verlag, 2010); Thomas Durisch (ed.) and *Peter Zumthor 1985-2013. Bauten und Projekte* (Zurich: Scheidegger und Spiess, 2014)

Excerpt from Mateo, Josep Lluis, and Florian Sauter. EARTH, WATER, AIR, FIRE: THE FOUR ELEMENTS AND ARCHITECTURE. Actar D, 2014.

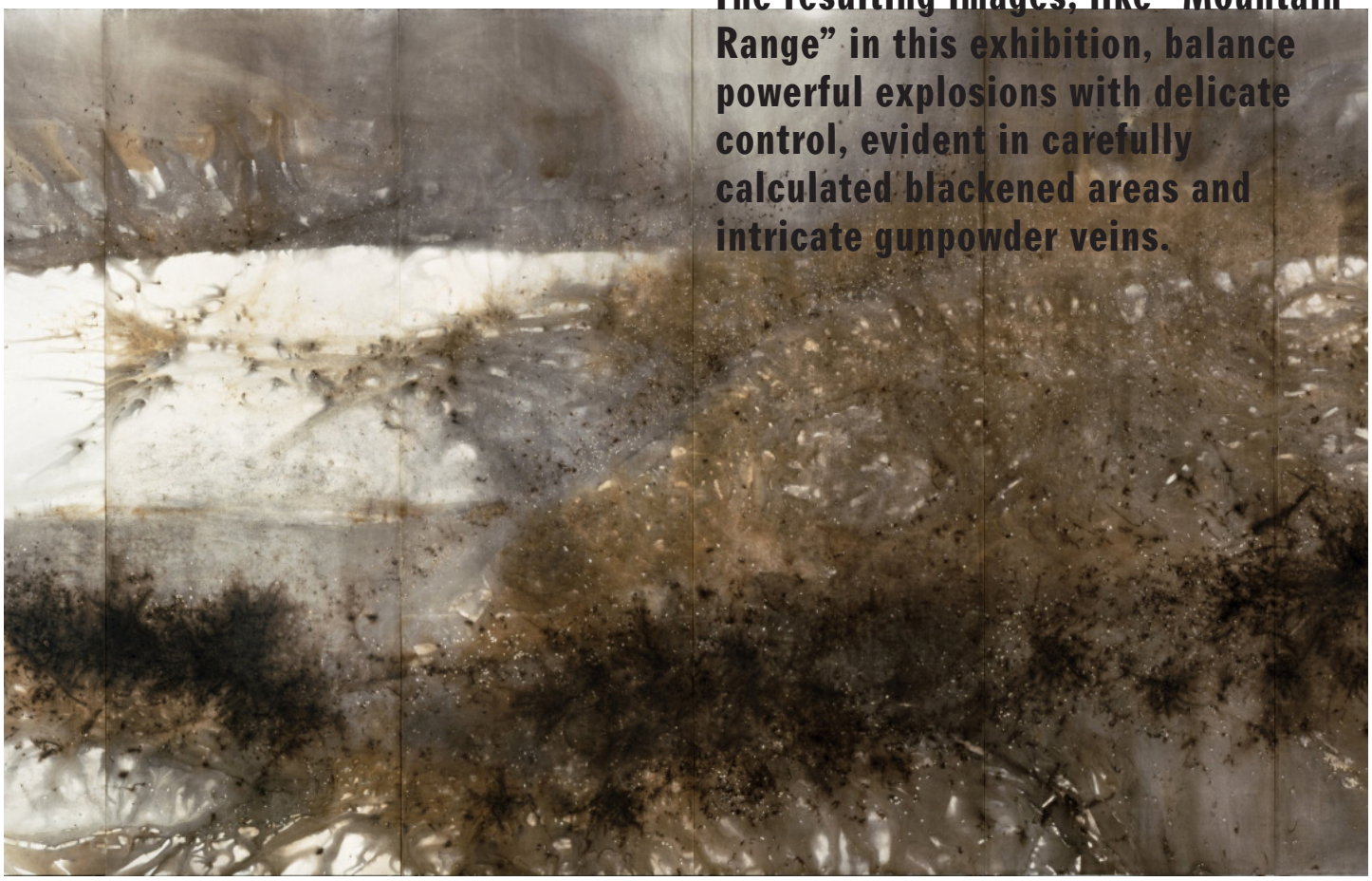
The Lightning Field, created in 1977 by American sculptor Walter De Maria, is a Land Art installation in the remote western New Mexico desert. Consisting of 400 polished stainless-steel poles arranged in a one-mile by one-kilometer grid, each pole is two inches in diameter, reaching an average height of 20 feet, 7½ inches. Positioned 220 feet apart with solid pointed tips defining a horizontal plane, the installation is meant for both viewing and walking, encouraging an extended, immersive experience.

Walter de Maria, LIGHTNING FIELD, 1977.

Toba no Himatsuri, the Shinto ritual of Toba Shinmei Shrine, has been practiced for about 1,200 years. Annually on the second Sunday in February, Toba Shinmei Shrine in Nishio City hosts a fire festival, featuring two 5-meter, 2-ton "Suzumi" torches. After purification rituals in the sea, the festival's spectacle occurs in the evening, as the Shin-otoko leaps into the blazing "Suzumi" to retrieve the sacred tree, symbolizing a divine competition. This intense spectacle showcases fearless participants challenging the flames in a captivating display.

THE TOBA FIRE FESTIVAL, Japan.

The artist developed an innovative method for controlling explosive gunpowder paintings on large paper. After creating the painting, he placed it on the ground, distributed gunpowder, and strategically positioned fuse lines along his sketches. Detonations occurred under a cover, increasing pressure and preventing excessive burning. The resulting images, like “Mountain Range” in this exhibition, balance powerful explosions with delicate control, evident in carefully calculated blackened areas and intricate gunpowder veins.



Cai Guo-Qiang, MOUNTAIN RANGE, 2006. Gunpowder on paper, mounted on wood as a six-panel screen.

Cai Guo-Qiang, WHEN THE SKY BLOOMS WITH SAKURA, 2023, daytime

fireworks event, Iwaki, Japan.

MATTER AND HEAT

GLASS AND HEAT

GLASS BLOWING

Before starting the glass blowing process, the glass is placed in a furnace that heats it to a temperature of 1400 – 1600°C (depending on the type of glass used), making it soft and malleable. Next, the glass is gathered by inserting one end of the blowpipe into the furnace and rolling it over the molten glass until a "gob" of glass attaches to it. The next step is to roll the molten glass on a flat metal slab called a marver. The marver acts as a way of controlling the shape and temperature of the glass. The glass is taken back and forth from the marver to the glory hole, a hot chamber used to reheat the glass, in order to make it malleable again. To give the glass colour and design, the "gob" can be dipped in crushed coloured glass. After colouring, it is taken back to the marver where it is rolled again. To give the glass its final shape and size, it is blown into with a blowpipe, creating a sort of bubble of glass, and manipulated using a range of tools, such as a cast iron cupping tool, folded wet newspapers and wooden boards. To carry out this process, the blowpipe holding the glass must be placed on a steel stand. Then, the glass artist has to blow into the blowpipe while rotating it at the same time. Throughout this process, the glass needs to be continuously taken to the glory hole to be reheated because blowing it cools it very quickly. The final step is to remove the glass from the glass pipe. To do this, steel tweezers called jacks are used to separate the bottom part of the blown glass while rotating the blowpipe. Thanks to the separation with the jacks, the glass can be removed from the blowpipe with one solid tap. The last step is to take the blown glass to an annealing oven, which allows the glass to cool slowly over several hours, as it is highly perceptive to cracking when exposed to rapid temperature changes.

Blow Moulding A gob of molten glass is gathered onto the opposite end of the blowpipe and a little air is blown into it through the tube. This preliminary shape is then lowered into a mould and inflated by blowing until it has assumed the desired shape and pattern of the mould. The mould may be constructed from one disposable piece, in which case it is broken off the glass piece, or it may be made from two pieces and able to open, which allows the mould to be removed and reused.

CASTING KILN CASTING

The process of heating glass above or inside a refractory mould until it melts and fills the void. First, the mould is placed in a kiln and filled with pieces of glass (normally recycled glass). The furnace is heated gradually, up to 1400°C. At this temperature, the glass melts

and fills the mould, and bubbles rise to the top. The furnace is then gradually cooled, over about 12–14 hours to prevent the glass from cracking. Once at room temperature, the mould can be removed leaving the cast which has taken the shape and texture of the mould. There are two types of moulds that can be used in kiln casting: open-faced or closed/ semi-closed. When using an open-faced mould, your finished piece will be a reverse-relief, bas-relief, pâte de verre, thick-block or box castings. When using closed or semi-closed moulds, you will be able to make full sculptural pieces.

Sand Casting When sand casting, a design is placed or carved into treated serpentine sand to create a mould. Then, using a ladle of molten hot glass, the glass is poured into the sand mould and given time to cool. Once the glass is cool to touch, the sand can be pulled away to reveal a solidified casting with a rough textural finish, which can then be polished.

Lost Wax Casting Using this method of glass casting captures finer details. First a design is created in wax before building a mould around it. The wax can be shaped with texturing tools, in order to effectively sculpt and carve unique designs in wax. For the mould that goes around the wax, it is possible to create your own by combining equal measures of plaster and silica. Plaster gives the mould support and silica has a high refractory, so it can withstand a lot of heat. After embedding the shape into the mould mix and allowing it to set, the piece is heated which melts the wax inside, leaving a cavity. It is then placed into a kiln and heated, where, at the right temperature, molten glass flows from a reservoir into the mould. The critical stage of the process occurs as the glass cools and the molecules bond and the glass anneals, which prevents possible breakage in the future. In this way, the annealing phase (controlled cooling) takes days if not weeks, depending on the size of the sculpture.

THERMOFORMING / SLUMPING

Thermoformed glass is glass that has been heated to a temperature where it becomes soft and then moulded via gravity over a shape, in order to form it and give it a texture. It is a process that is better suited for making flatter objects, such as glass countertops, tables and related materials. First, a mould is made usually in iron, stainless steel or refractory ceramic. The glass panels are then cut to a size slightly larger than the mould. Once the glass is cut, it is brought to a kiln and placed on top of its relative mould. The kiln is heated to about 843°C and the glass starts to soften thus taking the shape and texture of the mould it is placed on top of.

POURED GLASS

It is possible to pour glass in a range of decorative ways. One such technique is called Trailing, where the worker pours glass threads, often in a contrasting colour, around a free-blown glass shape as it spins.

FUSING

Fusing is the bonding of compatible glass pieces together via heat, at around 818°C, and gravity in a kiln. You can fuse stacks of glass together or glass pieces cut and placed side by side, which allows the possibility of cutting the glass pieces into intricate designs.

MATERIAL GESTURE: GLASS, Studio Anne Holtrop, ETH, HS22.


PEVEKO
PEVEKO


ONLY

HEAT AND METALS

SAND CASTING

Sand casting is a metal shaping process that starts with creating a model of the desired object out of wood or metal. This model is surrounded by sand, forming a mould. After removing the model, the resulting hollow space in the sand mould represents the shape to be cast. Molten metal, often aluminum or bronze, is then poured into this mould and left to cool and solidify. Once the metal has hardened, the mould is opened, revealing the metal casting. Sand casting is one of the most popular and simplest types of casting, and has been used for centuries. Sand casting allows for smaller batches than permanent mould casting and at a very reasonable cost, but exhibit a rougher surface finish compared to other casting methods and is not the best method to cast detailed surfaces.

DIE CASTING

In the die casting process, molten metal is compelled under high pressure into machined mould cavities, typically created in dies. This method involves the utilisation of two substantial, movable non-ferrous metal components that tightly close together under high pressure. The molten metal is introduced into the die, and once it solidifies, the metal components are separated. While die castings are predominantly crafted from nonferrous metals like zinc, copper, and aluminum-based alloys, the possibility of ferrous metal die castings exists. This technique is particularly well-suited for applications requiring numerous small to medium-sized parts, characterized by precise details, a refined surface quality, and dimensional consistency.

LOST WAX CASTING

The investment casting process commences by injecting wax into a mould, which solidifies to create a wax model. Subsequently, this wax model undergoes multiple layers of coating with a ceramic material. The ceramic-coated assembly is subjected to heat, causing the wax to melt away and leaving behind a ceramic mould. Molten metal is then poured into this mould, allowed to cool, and the ceramic material is removed to unveil the final metal casting.

THERMAL EXPANSION IN METAL STRUCTURES

These examples showcase how heat can be used to modify architectural materials for various purposes, including shaping, dynamic adaptability, and accommodating thermal changes.

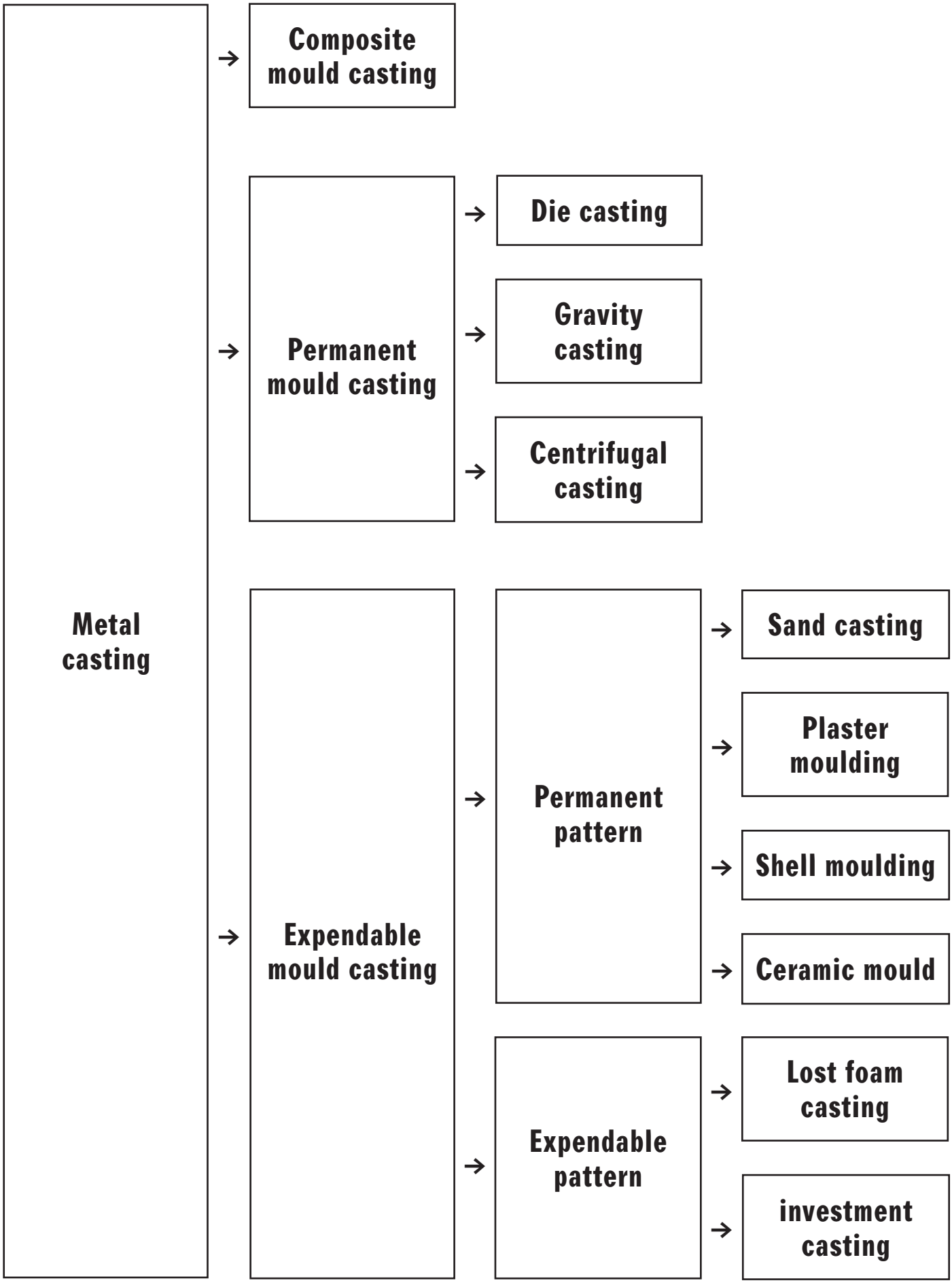
Material Metals, such as aluminum or steel, experience thermal expansion when heated.

Heating The metal component is subjected to heat, causing its molecules to gain energy and expand.

Assembly During assembly, allowances are made for the anticipated expansion, ensuring that the structure remains stable at various temperatures.
Cooling As the metal cools, it contracts back to its original size.

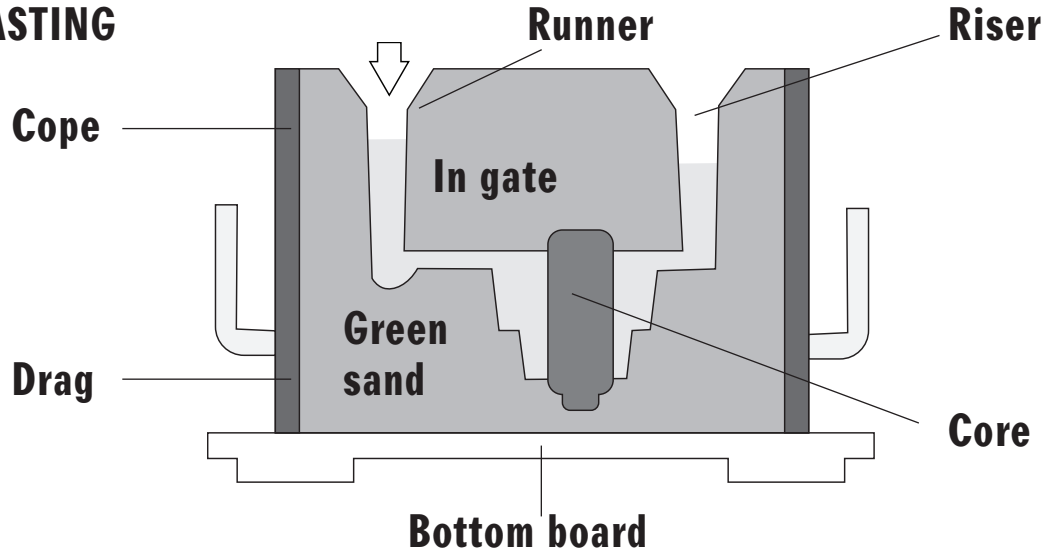
FORGING

Forging involves shaping a material, typically by striking it with a hammer or pressing it with a die. The material is often heated before forging to enhance the process, it remains solid throughout. Examples of products crafted through forging include kitchen knives and various knife blades.

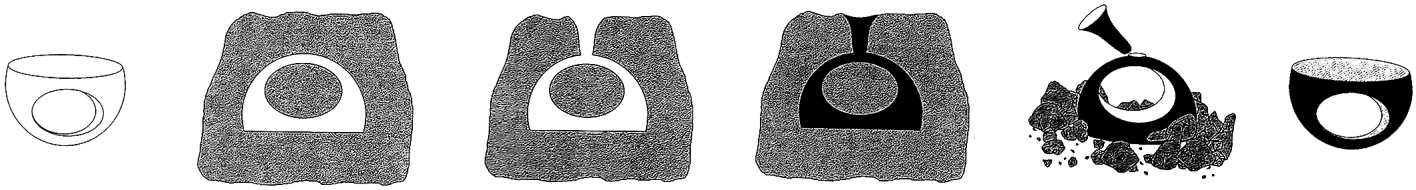


TYPE OF METAL CASTING

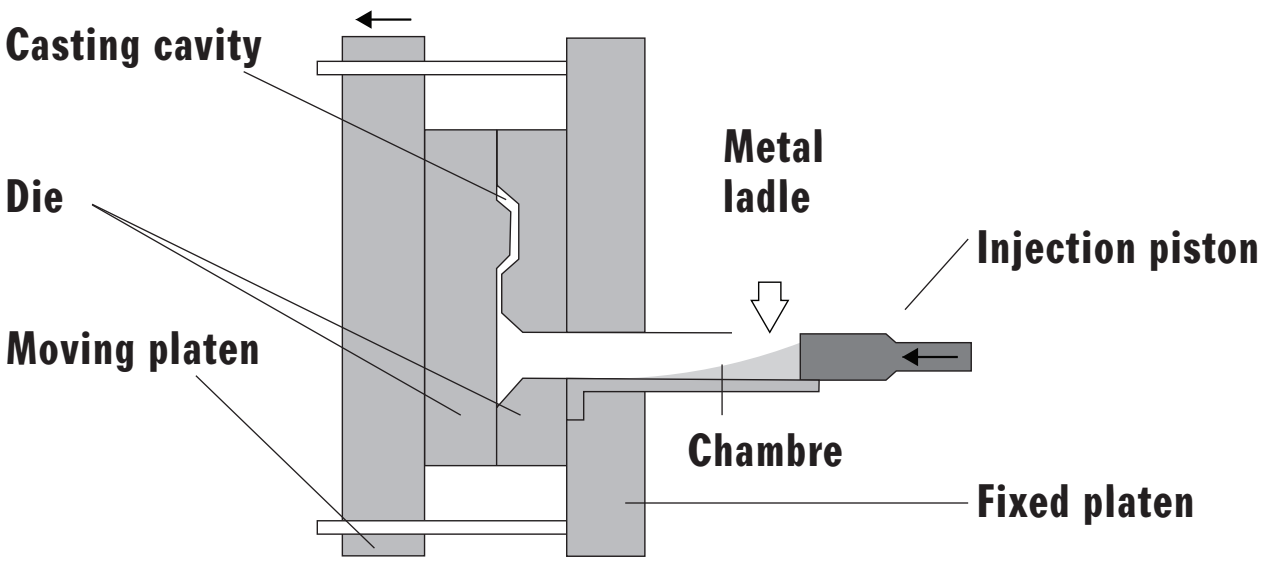
SAND CASTING



LOST WAX CASTING



DIE CASTING



METALS	CELSIUS
Wrought Iron	1482–1593
Carbon Steel	1370–1593
Cast Iron	1127–1204
Brass Red	990–1025
Brass Yellow	905–932
Titanium	1670
Stainless Steel	1510
Nickel	1453
Iron Alloys	1370
Steel	1205
Copper	1084
Bronze	913
Aluminium	660

MELTING POINTS OF METALS IN CELSIUS

METAL	PERCENTAGE
Aluminium	6.6
Copper	4.9
Magnesium	4.0 or 4.2
Zinc	3.7 or 6.5
Low Carbon Steel	2.5–3.0
High Carbon Steel	4.0
White Cast Iron	4.0–5.5
Gray Cast Iron	-2.5–1.6
Ductile Cast Iron	-4.5–2.7

SOLIDIFICATION SHRINKAGE OF VARIOUS METALS

KILN FIRING

SMALL SCALE AND LARGE SCALE KILNS

A kiln is constructed using refractory (non-melting) materials to build a chamber. Heat generated within this chamber and the pieces undergo the firing and subsequent cooling processes. Although clay can be fired in an open flame without the need for a kiln, kilns are best for achieving elevated temperatures. Additionally, they offer precise control over temperature fluctuations, safeguarding the ware from the challenges posed by the firing process.

TUNNEL KILN

The Tunnel Kiln is a firing kiln that is constructed on-site and operates by transporting products on kiln cars through the furnace. It delivers labor and energy savings, and can reduce the amounts of fuel used and amounts of CO2 emitted.

SAWDUST KILN PROCEDURE

1. Place a layer of sawdust in the base of the kiln. Lay a 2-layer clay brick base, and stack brick walls around the base building a box structure, keeping the kiln open on the top. Place a layer of sawdust in the base of the kiln.

2. Place the pieces to be fired in the kiln and surround them with sawdust. If you wish the fire to proceed fairly slowly (the safest option), pack the sawdust fairly tightly around the pieces. Cover the pieces with a layer of sawdust.

3. Place the metal lid over the kiln, temporarily leaving a gap of a few inches to create a bit of a draft.

4. Start the fire with pieces of paper and let this burn for a few minutes.

5. Close the lid of the kiln. During the first hour check the fire periodically and restart it if necessary. After 30 minutes the fire should be well enough established to stay lit until all the sawdust has burned.

6. Unload the pieces the next day and brush off any burned sawdust.

More detailed description at thepotterywheel.com/sawdust-kiln

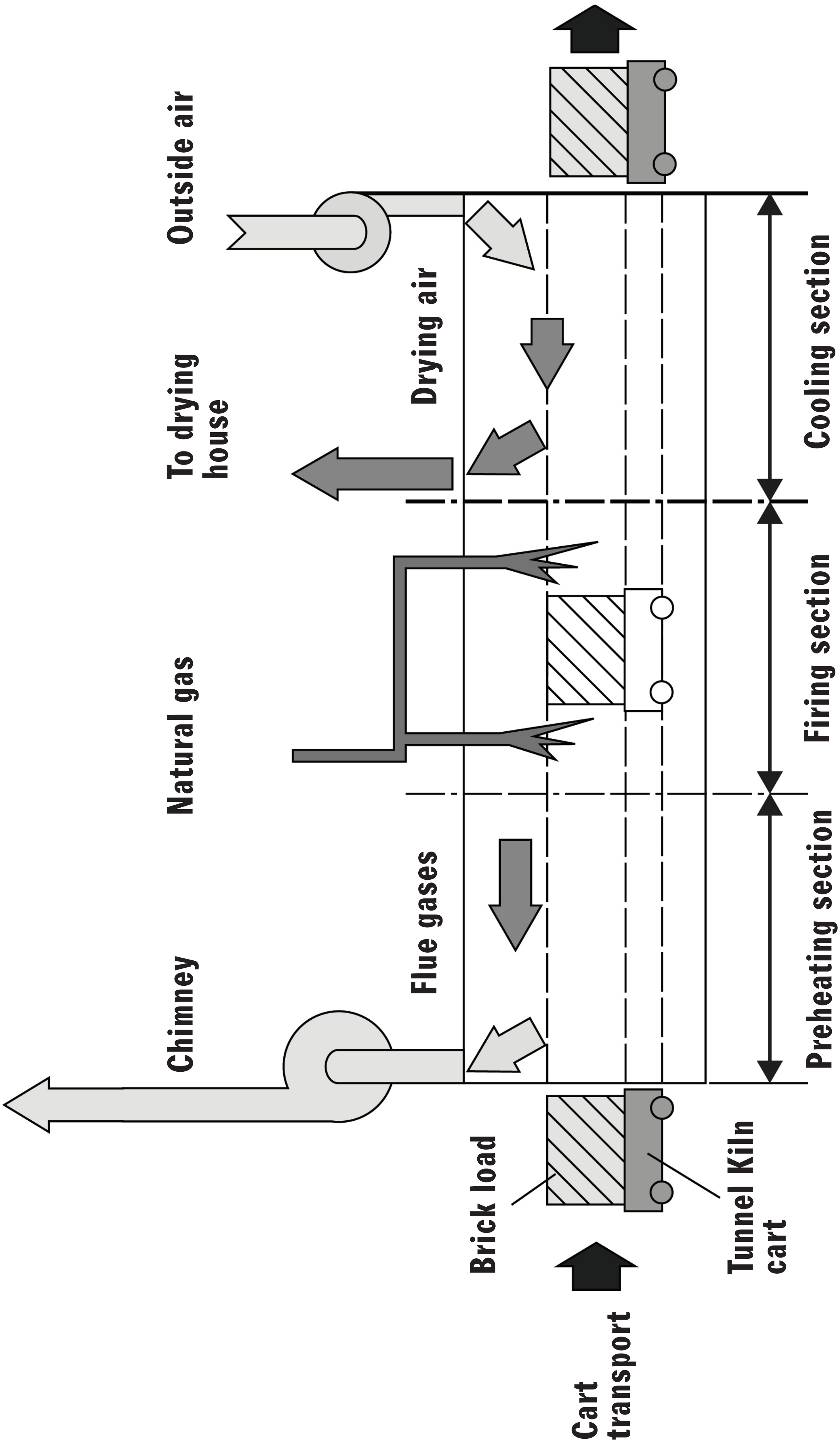


DIAGRAM OF BRICK/CERAMIC TUNNEL KILN SYSTEM

SMALL SCALE, HOME MADE SAWDUST KILN
104

TRADITIONAL BRICK KILN, INDIA

The process begins with the collection of suitable clay from local sources. This clay is then mixed with water to achieve the right consistency. The prepared clay is shaped into individual brick moulds. Traditional moulds are often wooden frames that give the bricks their desired size and shape. The freshly moulded bricks are set out to dry in the sun for several days. This step is crucial to remove excess moisture from the bricks and prepare them for firing. Once the bricks are adequately dried, they are arranged in a specific pattern inside the brick kiln. The arrangement is designed to facilitate even firing. The firing process involves heating the kiln to high temperatures to harden the bricks. Traditionally, the kilns are fueled by various materials, such as wood, coal, or agricultural waste. This firing process can take several days. After the firing process is complete, the kiln is allowed to cool gradually. Rapid cooling can lead to cracks in the bricks. Once the kiln has cooled down, the hardened bricks are carefully unloaded. They are now ready for use in construction. It's important to note that traditional brick-making methods are labor-intensive and often lack some of the efficiency and environmental considerations found in modern brick production. However, these traditional methods are deeply ingrained in local practices and have sustained communities for centuries. Efforts are being made in some regions to introduce more sustainable practices and technologies into traditional brick-making processes to reduce environmental impact.

BAKED IN SITU EARTH HOUSES

These residences are designed to house 15 children and 5 foster parents. The construction of this project incorporates an innovative technique pioneered by Ray Meeker of Golden Bridge Pottery. This method involves crafting a mud house in situ and then baking it to achieve durability. Termed as a fired house or fire-established mud house, this construction essentially entails using mud bricks and mud mortar to build a structure, which is then baked as a whole to attain the strength comparable to that of bricks. The interior space of the structure is filled with additional mud bricks or other ceramic products, such as tiles. The entire structure is then fired, resembling a kiln process. In traditional kilns, approximately 40% of the generated heat is absorbed by the kiln walls. However, in this unique technology, the house itself serves as the kiln, and the 'heat loss' is intentionally directed to fire the house and fortify it against water damage.

TRADITIONAL KILN FIRING: CHARCOAL PRODUCTION IN SWITZERLAND

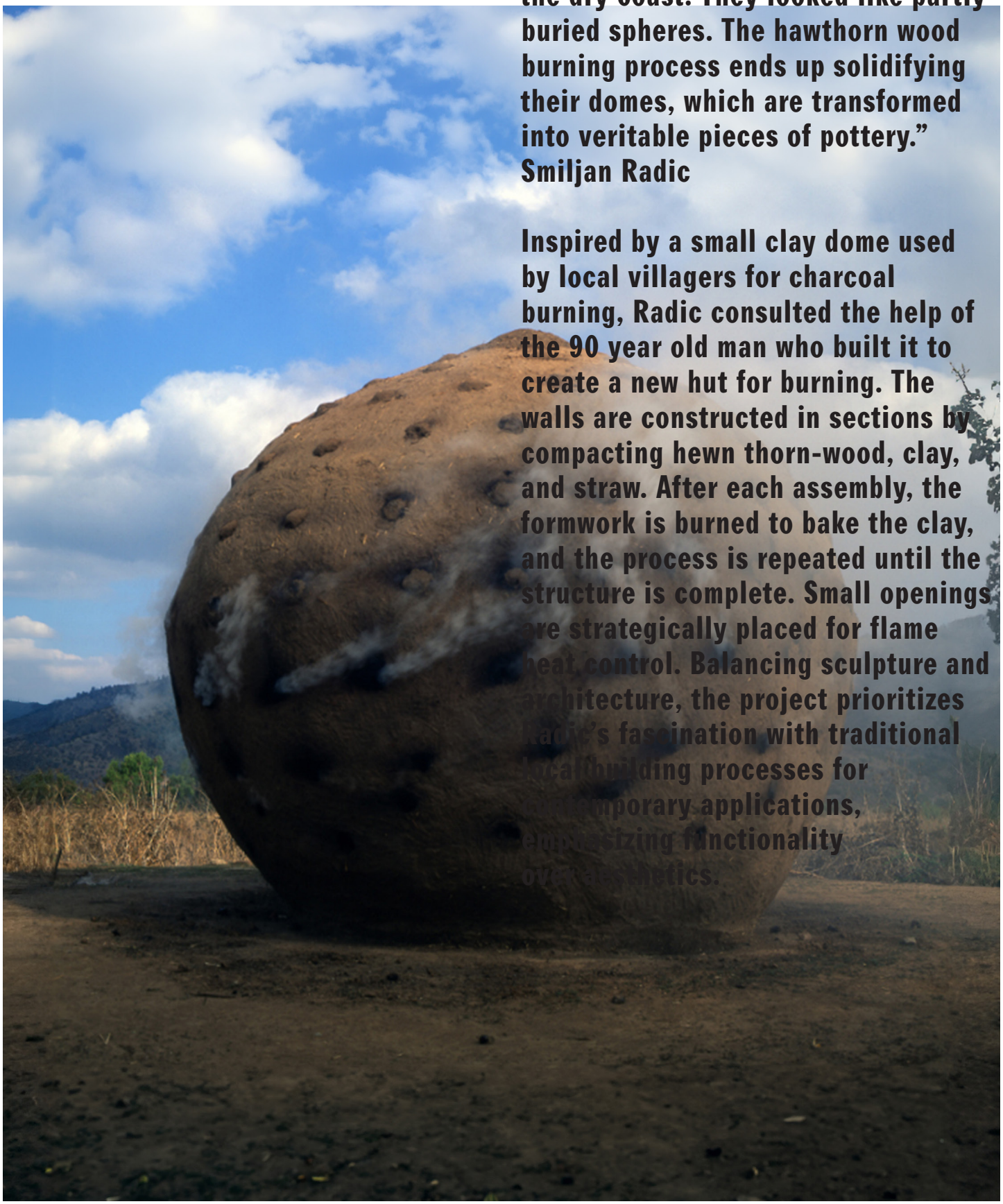
“Köhlern” involves the methodical burning of wood in a kiln to yield charcoal. The rural community of Romoos in the Lucerne municipality of Entlebuch stands as the last bastion of professional charcoal producers in Switzerland, who engage in this traditional craft to supplement their income. The hilly Napfbergland region has a longstanding tradition of charcoal production, dating back centuries. Due to the inaccessibility of forests by road, the local population turned to charcoal production, leading to the discovery of over 200 historical charcoal production sites in the Romoos community alone.

The most arduous phase of the process involves setting up and preparing an outdoor kiln. Layers of discarded wood are meticulously stacked to form a pile measuring around four meters in height and ten meters in width. Once ignited, the kiln burns for approximately two weeks, requiring constant supervision from the charcoal maker. The final, demanding step involves extracting the charcoal. Using this method, Romoos charcoal makers annually produce around 100 tonnes of charcoal. Historically, until the 1980s, their charcoal found its way to the steel industry. With the decline in that sector, the focus of charcoal makers has shifted to the barbecue coal market.

TRADITIONAL BRICK KILN, India.
108

Anupama Kundoo's baked in situ EARTH HOUSES, Volontariat Home for homeless children, India, 2008–2010.

Stills from the film. [illegible], 2017, Robert Muller, Switzerland.



"We came across some kilns that had been used to produce charcoal on the dry coast. They looked like partly buried spheres. The hawthorn wood burning process ends up solidifying their domes, which are transformed into veritable pieces of pottery."
Smiljan Radic

Inspired by a small clay dome used by local villagers for charcoal burning, Radic consulted the help of the 90 year old man who built it to create a new hut for burning. The walls are constructed in sections by compacting hewn thorn-wood, clay, and straw. After each assembly, the formwork is burned to bake the clay, and the process is repeated until the structure is complete. Small openings are strategically placed for flame heat control. Balancing sculpture and architecture, the project prioritizes Radic's fascination with traditional local building processes for contemporary applications, emphasizing functionality over aesthetics.

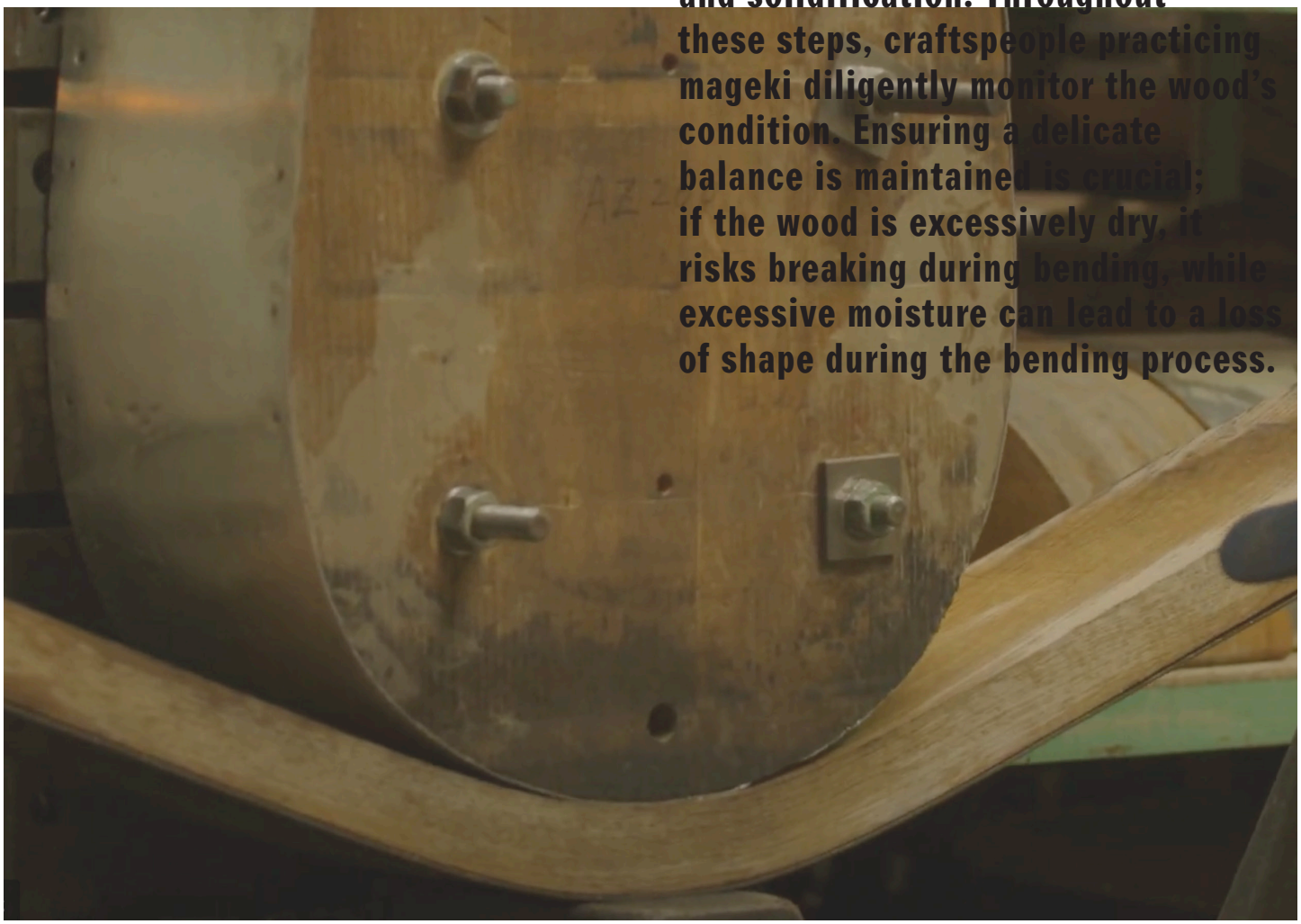
Smiljan Radic, EXTENSION TO A CHARCOAL BURNER'S HOUSE, Culipran, 1999.

STEAM BENDING (WOOD)

Japan: MAGEKI

In this images, the mageki (wood bending) technique is demonstrated by manually bending the tree cutting around a larger tree section, after it has been boiled in water. The tree cutting goes back and forth from the steaming pan, each time the artisan is able to bend it slightly more. At a certain point they add a string brace, to hold the bended shape in place while it cools.

In this video, the mageki (wood bending) technique is demonstrated within a woodworking workshop in Hida, showcasing its application on a singular, solid wood piece. The process begins with steaming the wood, followed by bending it using a mechanical press, and finally, securing it in a mould for drying and solidification. Throughout these steps, craftspeople practicing mageki diligently monitor the wood's condition. Ensuring a delicate balance is maintained is crucial; if the wood is excessively dry, it risks breaking during bending, while excessive moisture can lead to a loss of shape during the bending process.



youtube.com/watch?v=I8gZxXsXAqA

ROCK FORMATION

ORIGIN OF THE CORE'S CONCENTRIC LAYERING

The Earth formed around 4.3 to 4.5 billion years ago through the accumulation of planetesimals like meteorites and asteroids. In the final stages, a miniplanet collided with the Earth at a glancing blow, resulting in the creation of the Moon. If the impact had been direct, the Earth might have shattered.

The stratification of the Earth into dense core, intermediate mantle, and light lithosphere indicates a molten stage early in its history. This molten state, caused by factors like meteorite impacts, the moon's impact, and radioactive decay, led to material differentiation.

Around 4.3 billion years ago, the Earth would have appeared as a glowing red hot ball of magma. Geological activity today is a result of the initial heat source during Earth's formation, intensified by ongoing radioactive decay. While the Earth's heat engine ran faster in its early years, it is gradually cooling. Despite the current geological activity, the Earth is cooling off, and over time, there will be less heat to escape until it eventually experiences a heat death.

COOLING HISTORY OF PLANETARY BODIES

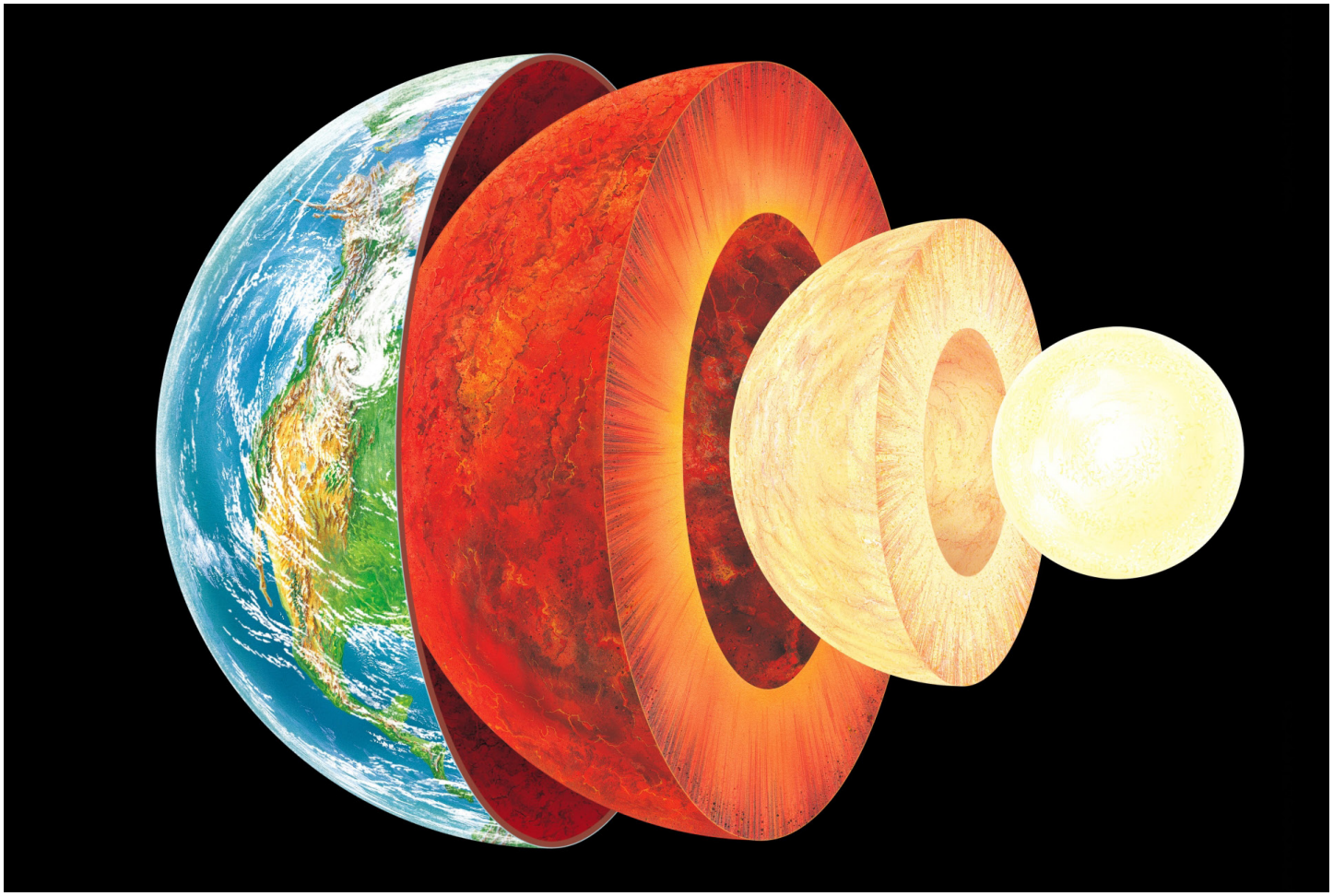
Around 4 billion years ago, the Earth had cooled sufficiently for its outer layers to solidify, giving rise to oceans. Flying past the Earth during this period, one would observe a vast ocean from pole to pole, with sporadic volcanoes but no continents – a scene reminiscent of 3.8-4.0 billion years ago. The oldest rocks, dating back to 3.96 billion years, contain evidence of sedimentary rocks indicating the presence of water.

The Earth's core, still molten with iron-nickel remnants from its early melting, is crucial for maintaining geological activity. Without this internal heat, essential features such as continents, volcanoes, mountains, oceans, and likely life would not exist on Earth, rendering it a barren planet like Mars or the Moon.

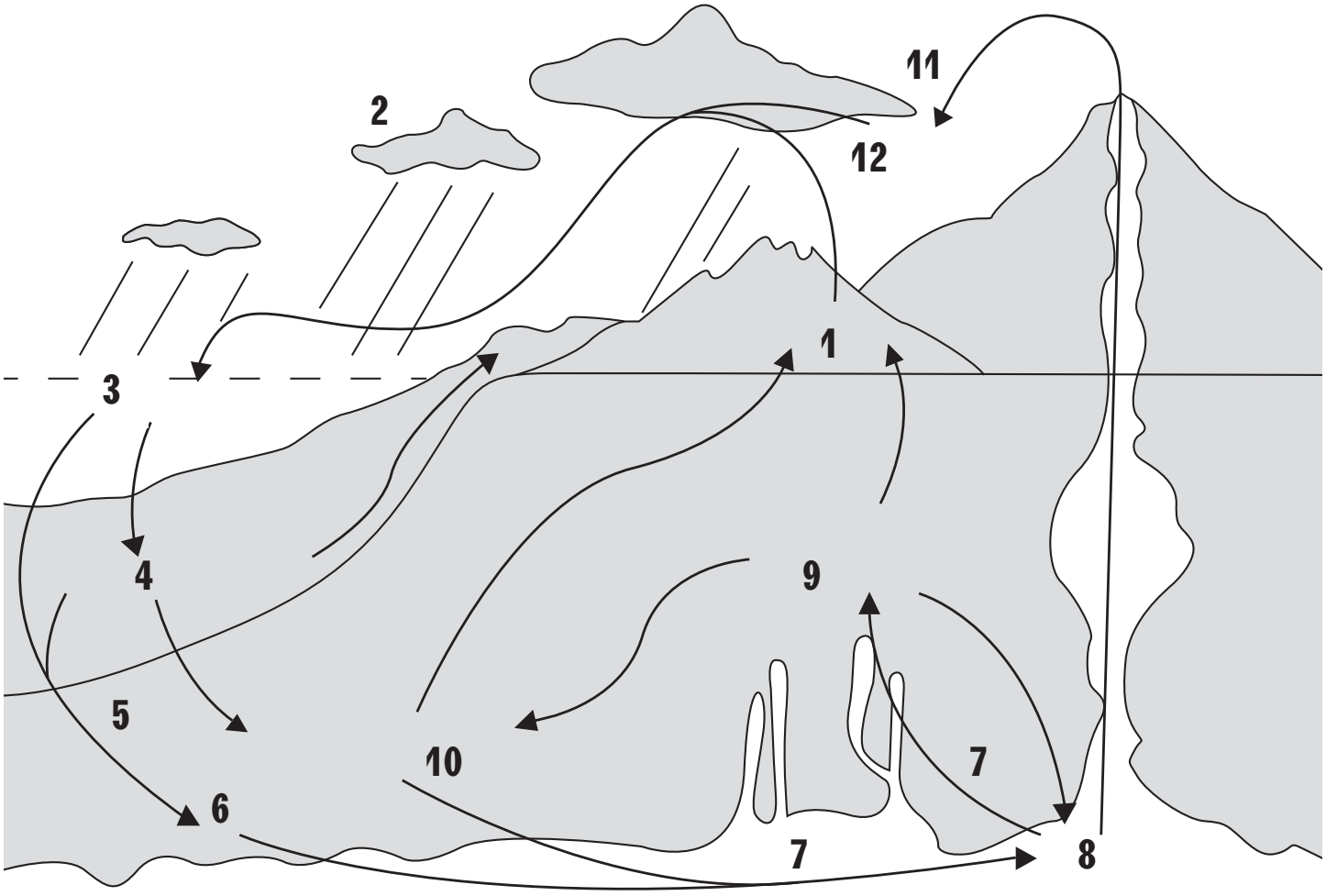
Unlike small planetary bodies like the Moon, which becomes geologically inactive within a few hundred thousand years, the Earth's larger size allows multiple heat escape mechanisms. The Moon, for instance, lost heat through volcanic activity induced by meteorite impacts, forming mare areas visible from Earth. Heat also escaped through conduction, although rock's poor heat conductivity means larger planetary bodies rely on alternative heat dissipation methods.

TYPES OF ROCK

Rocks are confined to the earth's crust, which is the thin, light outer solid skin of the earth, ranging in thickness from 40–100 kilometres (25 to 62 miles) in the continental blocks to 4–10 kilometres in the ocean basins. Underneath the earth's crust is another layer of mostly solid rock, called the mantle.Rock is always being formed, worn down into pieces and then formed again. This is called the rock cycle. Rock wears down through erosion. Pieces of rock then settle and slowly become sedimentary rock. If sedimentary rock becomes deeply buried, it may melt into magma. Then the magma may return to the surface as igneous rock. Deeply buried rock may also become metamorphic rock. The rock cycle takes many millions of years. Rocks are broadly classified into three types: igneous, sedimentary and metamorphic. This classification is made on a basis of origin and does not take into account mineralogic composition or physical properties. These names describe how each type of rock was formed.



CRUST, MANTLE, OUTER AND INNER CORE
126



1 Uplift and exposure
2 Weathering, erosion and deposition
3 Sediments
4 Sedimentary rocks
5 Metamorphism (heating and pressure)
6 Metamorphic rocks
7 Melting
8 Magma
9 Igneous rocks (intrusive)
10 Cooling
11 Solidation
12 Igneous rocks (extrusive)

READER

EARTH, WATER, AIR, FIRE: THE FOUR ELEMENTS AND ARCHITECTURE
Mateo, Josep Lluis, and Florian Sauter. Actar D, 2014.

Limits to Architecture: Between the Human and the Non-Human

Philip Ursprung

Again, the air in the realm of culture is thick with heavy words. "Fundamentals" is the topic chosen by Rem Koolhaas for the 2014 Architecture Biennale. "Sensing Spaces: Architecture Reimagined" was the topic of the spring 2014 exhibition at the Royal Academy of Arts in London. And *Gravity* was among the most successful films in the autumn 2013-spring 2014 season. How can we explain this cultural trend towards the essential, the basic, the roots? Does it compensate for the centripetal forces at work in the economy and politics? Is the call for solidity in art, architecture and film a reaction to the disintegration of the welfare state and the rising inequality between social classes? Is the interest in the primordial in the realm of visual culture an echo of the political shift to the right? Can we link the trend towards fundamentals in academe and culture to the rise of political fundamentalism?

Of course, architecture is never completely independent of economic and political trends. However, I would argue that the two phenomena are not related. Certainly, the work of Martin Heidegger, for decades ousted because of his sympathies with National Socialism, is back on the reading lists. But so are the texts of Karl Marx and, more recently, Thomas Piketty's *Capital in the Twenty-First Century* (2014), a study of the inequality of the distribution of wealth. Certainly there is interest in a mutual basis, a common ground–this was the theme of the Architecture Biennale in 2012 – but there is also a big appetite for critical dissent, for manifestos and revolutionary pamphlets.

Peter Zumthor's thermal baths in Vals (1996), with their spectacular emphasis on the elements, mainly water, stone and air, may still be a key reference for essentialism in architectural discourse, almost twenty years after their completion. But in the light of the controversy about land use in the Alps, subsidies from the Swiss Federal Government and the role of the tourism industry, this project is also seen as a radical political statement and an instrument that helps a remote commune to survive economically and shape its own future. Architecture practices in southern Europe are shutting down, and young professionals have no choice but to move to the busy construction sites elsewhere around the globe. They have every reason to feel bitter and look back in nostalgia. Yet the atmosphere in the field of architecture seems to be optimistic and speculative. During my most recent visits to Portugal and Greece, the students told me that they were looking forward to finding work – just not at home. In other words, the reactionary move in politics has not led to a *rappel à l'ordre* in architecture.

So, how should we interpret the renewed interest in the issue of the essential? And essentials are, of course, also the concepts of the elements: earth, air, fire and water.[1] The definition of these essentials goes back to the sixth century BC. At that time, these categories enabled humans to make sense of the world and imagine an inner logic that went beyond mythology. Since Antiquity, and particularly since the Enlightenment, scientific knowledge has moved elsewhere, and the meaning of the elements has changed. From the viewpoint of current architectural discourse, the elements are no longer categories that organize the phenomena of the world. Rather, I would argue, they evoke the limits of architecture, the difficult zone of transition between what is architecture and what is not. This makes them fruitful concepts, at least from my point of view, because they help us to focus on the borderline between what is fabricated and what is not – in other words, the relation between the *human* and the *non-human*.

Manolo Laguillo, *Diagonal*, MACBA Collection, 1988-1989

Seen from this viewpoint, the discussion of architecture and the elements is a way to approach new paths. In particular, I consider the choice of these terms an alternative to the mainstream of architectural discourse, which relies on binary models such as city versus landscape, architecture versus nature, or modern versus postmodern.[2] The discussion of urbanism has widened our horizon and opened our eyes to phenomena beyond the object. However, it has also channelled our perception. Today, it is almost impossible not to consider the built environment and the urban as synonymous. Societies the world over – so we are taught in surveys and exhibitions – are consistently attracted by the metropolis. In the near future, we are repeatedly told, almost all humans on the planet will live in cities. In other words, the grand narrative of the urban has replaced the grand narrative of progress that dominated the nineteenth and twentieth centuries.

At the same time, nature once again becomes the focus of our attention in the form of global climate change and frequent natural disasters, and as the increasingly popular destination for domesticated natural beauty, retreat and recreation. What is meant by the urban and nature, however, is largely still up for debate. How can we resist this dualistic, teleological way of thinking? How can we focus more clearly on the interrelation between the human and the non-human? Discussing the relation between architecture and the elements is a way to deal with this issue. Since there is no way to define the elements of air, water, earth and fire – "what is?" is not an applicable question – they can be used as miniature theories in the style of Mieke Bal.[3] They incite us to think about the relation between architecture and something else, thereby helping us escape the self-referentiality of architectural discourse.

The notion of air literally brings in fresh air to the discussion. It enables us to enter the debate on climate change as well as the common good of fresh air, but it also includes issues such as wind and storm. It makes us think of the atmosphere as a vital part of our existence as well as our feeling at ease in a space. And it refers to the issue of volatility, change and ephemerality that challenges traditional use of materials. The notion of earth brings the discussion to the ground. It allows us to discuss the relation with the materiality and topography of the ground as well as the materiality of construction. It heightens our consciousness about the relation between the human body, the ground and the built space. It makes us think about gravitational forces, but also about the long time span reaching back to the formation of the surface of our planet. The notion of water touches issues such as rain and snow, but it is also intrinsically linked to our bodies, for instance in the guise of washing, bathing and drinking. It inspires us to think about the symbolic meaning of water as well as its function. It opens doors to the origins of life on earth, to fluidity, transformation and expansion. Without water, life and movement are unthinkable, but how can we represent it in terms of architecture? And the notion of fire can literally heat up the debate, introducing the issues of heat, melting metal and firing bricks but also cooking, smoking and bathing. What does it mean that fire regulations are among the most influential factors in building use today? How can a project articulate the fact that, without fire, there would be no architecture – Gottfried Semper teaches us that the main function of architecture is to protect the hearth – and that fire is also the most dangerous enemy of architecture? As a motor of civilization and industrialization, fire is always present, yet it remains the most difficult to represent.

What distinguishes the use of the notion of elements from other systems of order is the fact that it aspires to universality and totality. To discuss one element as such, in isolation, is impossible; it inevitably leads to the others. And the four elements contain the idea of totality and completeness. This relates them back to architecture. Despite the many changes

that the profession has undergone since Antiquity, the word has remained the same. And the practice is still one that synthesises various practices and speaks of coherence and totality, from the idea to the sketch, and from the model all the way to the finished building. It will never be possible to achieve totality, but architecture's ongoing longing for order and totality guarantees the discipline a secure place in the context of a constantly changing environment. Perhaps this explains the optimism of the profession and the lightness it maintains despite – or because of – the heavy words it has to use.

1 For a cultural history of the elements see Gernot and Hartmut Böhme, *Feuer, Wasser, Erde, Luft: Eine Kulturgeschichte der Elemente* (Munich: C.H. Beck, 1996).

2 This topic was discussed at the conference "Urban Nature: Between the Human and the Non-Human", co-organised by Philip Ursprung and Mark Wigley at the Center for Architecture, New York, 16 May 2014.

3 See Mieke Bal, *Travelling Concepts in the Humanities: A Rough Guide* (Toronto: University of Toronto Press, 2002) p. 22.

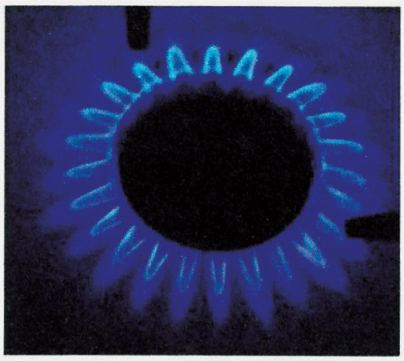
Light and Heat
Manfred Sigrist

For natural scientists, fire is the release of stored chemical energy in two ways: one is *light*, based largely on quantum mechanics. In the atom, different electron orbits correspond to different energies. An electron can jump up between these orbits, absorbing a light quantum, a *photon*. They can also hop down, which we call a quantum leap that releases a photon. Since this quantum of light has a fixed energy and frequency, we can see different atoms by just looking at the different colours of a flame. For example, sodium has a yellowish flame; copper, green, and lithium, red. In addition, when looking at a flame, we notice a slight change of colour from bottom to top that has to do with *black-body radiation*. For instance, when a metal is heated up, we observe a colour gradient from black to red to yellow and white, where the white part is the hottest, and it is here that the most carbon – the soot – leaves the material through oxidation. The temperature indicates where the maximum intensity is: it can be ultraviolet if it is very hot, infrared where it is very cold, or in the visible range of colours from blue (warm) to white/green/yellow (medium) and red (cold). If a flame is hot, it can also ionise the atoms around it, stripping the electrons from the surrounding atoms to create a field of charged gas particles. Light is, then, a convertible electromagnetic energy.

The other way to release energy by fire is through *heat*, which is, however, leaky and diffuse. The *first law of thermodynamics* states that heat is a form of energy, and energy is always conserved. The first part means that we can use heat as a form of energy to boil something. Whether it is gaseous, liquid or solid, it is the motion of the atoms that gives rise to heat. As stated, it is an uncontrolled motion and, in this respect, different from mechanical, electrical or chemical energy. The second part of the first law means that all the internal energy of a system is either heat or work delivered; in other words, work is all energy that is not heat. For example, in a car the fuel is the thermal energy and, once fired up, it will be converted into controlled motion (25%), while the rest is lost by damaging the tyres and through waste heat. This last term indicates that heat is not used for anything useful and just dissipated. This aspect of wasted heat is contained in the *second law of thermodynamics*, which states that heat cannot be transformed completely into another form of energy. This leads to the concept of *entropy*: a simple example is a partitioned system with a hot and a cold part called *frozen equilibrium*. When the partitioning wall is removed, a heat transfer occurs that leads to *global equilibrium*, where the temperature is the same in all parts, but the entropy has increased. Once there is global equilibrium, the heat can no longer be converted into another form of energy. In general, the greater the entropy, the less useful a system, and the smaller the entropy, the more is known about

a system. This energy potential in a frozen equilibrium can be used, for instance, in a cyclic heat engine. As far back as the first century, Heron of Alexandria devised such a machine: a pot with water is heated by fire, the heat makes the water boil, and the rising steam is channelled through tubes into a ball with two outlets. There the steam passes into the air and sets the ball into rotation. In all cases, for the conversion of heat into motion two reservoirs are needed: first, a hot one that provides the energy to generate work; and second, a cold reservoir into which some of the heat is dumped, since not all of it is transformed into work. The *Carnot ratio* indicates the relation between the work that is produced and the heat that is taken out from the hot part. As already mentioned, if both reservoirs have the same temperature, there is no heat transfer, no energy coming out and, ultimately, no work produced.

Here is a *modern-day spinning machine* that is operated by just a minor temperature difference: there is a piston at the top in an airtight chamber connected to an almost frictionless wheel, and another, non-airtight piston at the bottom that separates two air spaces, one above and one below it. A hand placed beneath it will make the warm air expand and push the piston up. The displacer then moves down, causing the air to be in contact with the upper (colder) plate. The air then cools and contracts, which causes the small piston to move down again. The resulting oscillation of air pressures propels the engine. Interestingly, if ice is placed beneath it, it will propel in the other direction.



L *Light* as the product of a candle flame
R *Heat* as the product of a gas flame
Photo: George Shuklin

Steel Mill in Canton, Ohio
Photo: Scott Shaw

The ancients saw fire as the primeval element, the origin of the formation of matter. In our field, architecture, fire is associated with energy, with the thermal adaptation needed for human life, and for handling and producing the materials (iron, glass, food) that are fundamental for survival. Fire is a synonym for the flow of life, which architecture serves.

Generally, fire is connected to energy, light, purification, illumination, creation, destruction and metamorphosis. It has the classical properties of hot and dry, and once people ignited the first fire and gathered around it, it meant overcoming the hostility of the environment and appropriating the natural givens to human needs. As a synonym for humankind's transcendental powers, fire stands at the origin of radiant warmth and light. However, if not properly tended, its benign character can quickly become a dangerous and apocalyptic nightmare. Ultimately, the fireplace is the centre of the house: the hearth, connected to the vertical movement of the dancing flames and smoke.

Fire has no precise consistency, but its presence can actively transform matter into different states. Places of production where fire is active are truly impressive and magical. Out of a river of fire, all manner of shapes later materialize and solidify.

Josep Lluís Mateo

THERMAL DELIGHT IN ARCHITECTURE
Heschong, Lisa. M.I.T. Press, 2002.

Preface

This work began with the hypothesis that the thermal function of a building could be used as an effective element of design. Thermal qualities—warm, cool, humid, airy, radiant, cozy—are an important part of our experience of a space; they not only influence what we choose to do there but also how we feel about the space. An analogy might be drawn with the use of light quality as a design element, truly a venerable old architectural tradition. The light quality—direct, indirect, natural, artificial, diffuse, dappled, focused—can be subtly manipulated in the design of a space to achieve the desired effect. Thermal qualities might also be included in the architect's initial conception and could influence all phases of design. Instead, thermal conditions are commonly standardized with the use of modern mechanical systems that can be specified, installed, and left to function independently of the overall design concept. Indeed, environmental control systems tend to be treated rather like the Cinderella of architecture; given only the plainest clothes to wear, they are relegated to a back room to do the drudgery that maintains the elegant life-style of the other sisters: light, form, structure, and so forth.

I became intrigued with the design potential of thermal qualities

when I was working on the design of a solar building. Rather than simply housing an autonomous mechanical system, the building itself acted as the thermal system. The living room was both for living in and for collecting heat. The south windows allowed a view and also let in the warmth of the winter sun. Thermal shutters, closed at night, made the house more introverted while also saving heat. I began to wonder how the thermal qualities of this building affected peoples' experience of it. I realized that there were very few references on which to draw. The one obvious analogy was the fireplace. The solar-heating functions of the building were essentially a replacement of the original thermal functions of the fireplace. With its circle of warmth, the fireplace had once been the center of family life. Its dancing light, smoky smells, and warm crackling created an ambience that made a house more a home. And the traditions around the hearth stretched back through the ages, connecting each house to deep cultural roots. How might the solar house incorporate some of the richness of the hearth? What were the qualities of the hearth that made it so wonderful and so beloved?

I decided to look not only at hearths but at places with strong thermal qualities from a broad spectrum of cultures and historical periods, with the assumption that there was a universality of human experience that might be distilled from them. I have looked at the examples not with the eye of a historian (How did it come to be?) or of an engineer (How does it work?) but rather with the eye of a designer

(How is it perceived? What role does it play in peoples' lives? What is wonderful about it? How is it part of a greater whole?). Unfortunately, information on peoples' actual use and experience of places tends to be sparse. It is perhaps a sad commentary on the state of architectural literature that so little attention is paid to how people ultimately use spaces and what they feel about them. The most illuminating descriptions are often written by anthropologists, literary travelers, or poets.

Other than the hearth, perhaps the richest example of a thermal place with a profound role in its culture is the Islamic garden, the cool oasis that is the traditional center of the Islamic house. Together they might be regarded as two archetypes: the hearth, a refuge of dry warmth from a cold world, and the oasis, a preserve of coolness and moisture in a desert wilderness.

It is hoped that this collection of disparate examples may serve as a set of references for the designer. It draws no firm conclusions and sets no guidelines; rather, it offers some background information and a bit of musing, which are the first stages of any design work.

Sacredness

Fireplaces have a more significant position in the American home than a simple analysis of their function would indicate. People love having a fireplace, even if they rarely use it. The ostensible function of the fireplace, to provide a source of heat for the house, has long been taken over by far more efficient central heating systems. When a fire is lit, it is likely to be a ceremonial event: a way to make the house feel especially homey, a treat when guests come to visit, a way to give an added air of celebration to a holiday such as Christmas or New Year's. Many modern houses have fireplaces installed with jets of gas that flicker about a permanent concrete log, intended to give the sense of a hearth without the fuss of having to actually build a fire. In such cases it is clear that the fireplace is valued more for its symbolic role than for its thermal function. The meaning the fireplace holds is an extremely important element of what it is. Thus, the hearth is as much a symbolic center of the home as it is a place for burning wood.

There are many other thermal settings in addition to the fireplace that have remarkable significance within their cultures. They are apt to have many layers of meaning, from the most personal, distilled from an individual's unique set of experiences, to those inherited from the experience of a culture as a whole. Yi-Fu Tuan in *Topophilia*, his study of how and why people develop a "love of place," writes that "A symbol is a repository of meanings. Meanings arise out of the more profound experiences that have accumulated through time."[1] To the extent that a place becomes a repository of meanings

valued by a culture, it also acquires value by its association with those meanings. In the same way that one can come to love a book because it contains important ideas, so, too, one may value an object or place for the ideas it embodies. In a sense, the place in its role as a symbol stores the idea, giving it a physical reality outside the mind.

In religious societies sacredness is a way to communicate the extreme importance of a symbol to society. When a symbol represents something considered essential to human experience, its preservation is of paramount importance. By deeming it sacred, a symbol becomes inviolable, ensuring its survival through time. The sacredness of the domestic hearth is common to many cultures. Our own concept of the primacy of the hearth may include the image of a fire burning brightly in the parlor of a nineteenth-century family or perhaps stretch back a century or two earlier to the huge central fireplaces of early New England houses. The meanings attached to the hearth, however, have accumulated through a much longer history. They are reflected in traditions having ancient, perhaps prehistoric, roots.

The hearth developed especially great significance in Europe, where pagan religions formed a foundation of ongoing folk traditions long after the establishment of Christianity. Many of the traditions probably grew out of early fire worship rites. It is clear that fire gods were prominent in the pantheons of the Indo-European peoples. The Aryans of Vedic India worshipped the fire god Agni. "He was man's domestic friend, the father of the sacrifice, the mediator between men and gods, the bearer of hymns and prayers from every family altar upwards towards heaven."[2] At the other end of the continent the Irish Celts worshipped Bel, or Baal, to whom they lit great bonfires each May Day, also known as Beltane Eve. James Frazer argues that the great fire festivals of Europe were linked to the annual death and

resurrection of the sun: "From the standpoint of primitive man nothing might seem more appropriate than to kindle fires on earth at the two moments when the fire and heat of the great luminary in heaven begins to wane or to wax."[3] Indeed, the solstices, and for some tribes, the equinoxes, were occasions for building huge ceremonial fires, such as the great bonfires burned on Midsummer's Eve in villages all over Europe up through the nineteenth century (and still continuing in Scandinavia). Yuletide, which has come to mean the Christmas season, was originally the name for the heathen winter solstice fire festival. The English custom of the Yule log, which is burned for the Christmas Eve fire, often from a charred fragment saved from the last year's Yule fire, is a remnant of the pagan fire ceremony that has been absorbed into the Christian customs. Frazer explains:

> Certain it is that the winter solstice, which the ancients erroneously assigned to the twenty-fifth of December, was celebrated in antiquity as the Birthday of the Sun, and that festal lights or fires were kindled on this joyful occasion. Our Christmas festival is nothing but a continuation under a Christian name of this old solar festivity; for the ecclesiastical authorities saw fit, about the end of the third or the beginning of the fourth century, arbitrarily to transfer the nativity of Christ from the sixth of January to the twenty-fifth of December, for the purpose of diverting to the Lord the worship which the heathen had hitherto paid on that day to the sun.[4]

The hearth was commonly considered the domestic sanctuary of a fire god. It might have housed a major god who was accepted throughout a whole culture, as in the case of the Agni of the Vedic Hindus, or a small local spirit who was responsible only for the protection of the individual house and its residents. In English folklore there is the tradition of the wise cricket who lives in the hearth and brings good luck and protection to the family. The notion may have originated with the chirping of a real cricket taking up residence in the recesses of the fireplace, but it also seems to have become a diminutive version of the ancient fire spirit who lived in the hearth. Much of the content of these traditions has long ago been abandoned or forgotten; yet they have left a sort of emotional residue, or a vague cultural memory, that continues to contribute to the cultural significance of the hearth.

The sauna presents an example rather closely related to the hearth. In Finland it has a very important place in national custom. The present-day rituals surrounding the sauna are similar to those of the Japanese bath. Although the Finns usually go to the sauna only once a week, in contrast to the daily visits of the Japanese, the sauna remains important as the place and the time for the family to relax together. H. J. Viherjuuri writes, "Reference to the sauna found in ancient folklore proves that it was generally known long before the beginning of modern times." It is clear that by the middle ages the sauna was important both in the routine life and the festivals of the Finns. "They went to the sauna every day to cleanse themselves; there they prepared for great festivals, and there they bathed before wedding ceremonies. . . . Many a child was born in the sauna and many an old man and woman carried there to die."[5]

Viherjuuri explains how the sauna was involved in the religion of the Finns:

> The sauna was a place for the worship of the dead, who were supposed to return gladly, even after death, to so pleasant a place. . . . Some people believed that the throwing of water over the stones was a form of sacrificial ceremony. The Finnish word *loyly,* meaning the "steam which rises from the stones" originally signified spirit, or even life. . . . "In the sauna one must conduct oneself as one would in a church," according to an old Finnish saying. It was forbidden to make a noise or to whistle, or to speak indecently in a sauna, because all evil influences had been driven out.[6]

Although many of the old customs are no longer observed, the sauna continues to be regarded by the Finns with a certain reverence, a reflection of the ancient traditions.

It is interesting that the sauna seems to have evolved from the form of an ancient house of the Finnish-Estonian people. The sauna developed as a log cabin when the technique for building vertical walls of logs or boards was introduced to the northern forest lands of Europe. This sauna house replaced the previous pit house, a tepee-like structure, which has also been retained in Estonian custom as the summer outdoor kitchen. As building technology advanced, the Finns and Estonians adopted larger houses, but kept the small sauna house as an outbuilding used specifically for hot air baths.[7] It would seem that the early form of shelter became so strongly associated with its thermal function, to provide a warm place in a cold climate, that it was retained for an exclusively thermal use.

The fire of the hearth and the steam of the sauna were rather

mysterious phenomena for our ancestors, which they explained in terms of their theory of how the world worked—a cosmology composed of spirits and gods. Fire and steam were valued because they were elemental. They offered an experience of the purity associated with the spiritual realm, and thus provided a link between the physical world of human beings and our ancestors' conception of the principles of the universe. Whether as a manifestation of a domestic hearth spirit or as a sun god, the fire was evidence of the powers of the spiritual realm.

We are not now inclined to regard modern heating and cooling systems as representative of a spiritual realm. The physical principles involved in their operation are thoroughly understood; there is no mystery about them. The air conditioner fitted into the window sash or the gas furnace in the basement are not thought of as expressions of a myth or as some metaphysical concept. They are simply functional, designed according to straightforward engineering practice to serve their intended function as efficiently and conveniently as possible.

And yet functionalism itself can be a kind of religion. It is part of the cosmology of a mechanistic universe where all objects and physical phenomena behave only according to objective principles. Building systems, machines, appliances come to be regarded as having a reality independent of human beliefs, their form and function determined solely by physical laws. They are all, however, most fundamentally, artifacts. They all have their origins in the human mind and therefore are inevitably formed by, and expressions of, the values, attitudes, and prejudices of their makers.

From the fifties and sixties we have inherited numerous heating and cooling systems created within an ethos of universal convenience. Machines to maintain our thermal comfort were conceived of as mechanical servants, providing for our every need while, like an English butler, remaining as unobtrusive as possible. Systems have

been devised that can be given instructions by remote control or set to turn themselves on and off to maintain automatically the perfect thermal conditions. Portable unit heaters and air conditioners can be plugged in wherever a little extra warmth or coolness is desired. In addition to heating or cooling the air, appliances are available to exhaust stale air; to humidify it, so one's mucous membranes won't dry out; and to filter the air, so it will be free of all odors, dust, and pollen. The ideal seems to be a beneficent robot who will understand and meet all of its master's needs.

A striking contrast to the appliance approach to thermal comfort is seen in the ethos embodied in the design of passive solar-heated buildings. With the development in the United States of an ecological consciousness has come an attitude that we should not use technology to distance ourselves from the natural world; rather, we should strive for a more intimate, even symbiotic, relationship with natural forces. Solar design, especially in passively solar-heated buildings, provides a prime expression of these values and, thus, has come to be seen as a symbol of them.

Karen Terry's house in Sante Fe, designed by architect David Wright, is perhaps one of the most compelling passive designs. Stepping down its hillside site in four tiers, it nestles low into the ground. Thick adobe sidewalls create a strong sense of shelter and its banks of windows look resolutely to the sun. The image is very much of a house attuned to sun and earth. Rather than providing the convenience of a constant indoor temperature regulated by a thermostat, a passively solar-heated house may go through an air temperature flux as great as 20°F per day. People learn to live with this flux by putting on a sweater or moving to the part of the house with the most desirable conditions. Karen Terry follows the temperature changes in her house with a migration strategy similar to the Tunisians, who move through their courtyard houses according to daily and seasonal tem-

perature cycles. She works in the cool lower level where she has her studio, eats in the middle level, and sleeps and bathes in the warmest upper level. She feels that the house, with its openness to the sky and its responsiveness to the climate, helps connect her to natural rhythms. "Living in a solar house is a whole new awareness, another dimension. I have the comfort of a house with the serenity of being outdoors—protected, yet tuned in."[8]

Janius Eddy, who lives in a solar home in Rhode Island, shares Karen Terry's sentiments. He describes the meaning his house has come to have for him:

> It is not just the financial savings. We grow more in awe of the tenuous hold our lives have on this small planet, more convinced that the sun renews us, in an almost religious way. It has made us profoundly grateful that the sun is up there, the center of our universe, warming us up and keeping us alive. That atavistic sense of the elements that early man knew and felt has become part of our lives.[9]

A solar house, geared to both the people who live in it and the cycles of the sun, is seen to exemplify the human relationship to the natural world.

Such an attitude is quite reminiscent of the ancients' fire worship as a celebration of the death and rebirth of the sun. It suggests a parallel between the symbolism of the hearth and of solar buildings. They both domesticate an elemental force to provide for pragmatic thermal needs. They both bring a primal phenomenon into the realm of everyday experience.

In addition to being invested with meaning in itself, a thermal system may also be used to reinforce the significance, or enhance the

meaning, of other symbols. Interestingly, special thermal qualities are associated with symbolic places in many societies. Perhaps the provision of thermal comfort and delight is a way to emphasize the importance of the place for people. A simple example is the air conditioner in the boss's office. Along with the black leather chair and the deep pile rug, the air-conditioned office is a mark of executive prestige. The association of thermal comfort with status, as in the boss's office, seems to be a rather common pattern. The more expensive and difficult it is to provide thermal comfort, the more likely its use will be restricted to only those purposes deemed most important. Thus, in Saudi Arabia, if a family can only afford to air-condition one room, it is most likely to be the men's visiting room, the *ka'ah,* even though it is the room in the house used least frequently. Hospitality is an essential value of Saudi society, and so guests are given the best the family has to offer.

A mechanically cooled place is especially apt to be linked with symbols of status, perhaps because for so long excessively hot weather was considered inescapable. The heat was a great equalizer—something everyone had to endure, rich or poor, lowly or royal. While the problem of cold weather might be comparatively simple to remedy by building a fire or putting on an extra robe, the technology for countering hot weather was extremely complex and expensive. In medieval Islamic countries, incredible effort was expended to cool the throne or pleasure pavilion of the sultan. Elaborate waterworks were used to cool an area by evaporation. A prince in Alwar in India had his throne room in a marble pavilion that was "completely enclosed in a veil of spray falling from the cornice."[10] A similar approach was employed for the delectation of the Spanish sultan in Toledo: "In the center of the lake rose a water pavilion of stained glass adorned with gold. Here the sultan could recline in comfort on the hottest day, encircled by the glistening shower falling

from the dome. At night tapers were lighted to glow through the transparent walls."[11] Regardless of how much benefit he actually derived from the elaborate system of cooling, it certainly added to the aura of power and privilege around the throne of the sultan.

The public baths of ancient Rome are an example of a thermal place that developed into an expression of the social ideals of a society. In early Rome, baths were a luxury found only in the houses of the very rich, those who could afford to finance the transportation of water over long distances and the cost of fuel to heat it. Entrepreneurs devised the idea of building bathhouses that would be opened to the public for a small fee. Such public baths, or *thermae,* became extremely popular, for like the Japanese baths they were both a social gathering place and an important source of warmth for the Romans. (Historians never fail to comment on the great thermal discomfort of the standard Roman apartment house, stuffy in the summer and unheatable in the winter.) The Roman statesman Agrippa, who as a young man had been a magistrate in charge of the public baths, conceived the idea of creating a free public bath. It was a grand egalitarian gesture, certain to make the government popular with the people. The Roman historian Carcopino describes it as "A revolutionary principle in keeping with the paternal role which the empire had assumed towards the masses."[12] Agrippa founded a bath to be free in perpetuity—named after himself, of course. Later emperors continued the tradition, each vying to construct the most enormous and sumptuous bath of all.

These *thermae* were among the wonders of Rome. No expense was spared in their construction and decoration. The finest marble, collections of ornate sculpture, and elaborate mosaic work combined to make the baths incredibly opulent. They were huge buildings with great domed spaces for the baths and many ancillary spaces for the

other public uses incorporated into the complex. Carcopino describes how the spaces were used:

> Near the entrance were the dressing-rooms where the bathers came to undress. Next came the *tepidarium,* a large vaulted hall that was only gently warmed which intervened between the *frigidarium* on the north and the *caldarium* on the south. The *frigidarium,* which was probably too big to be completely roofed in, contained the pool into which the bathers plunged. The *caldarium* was a rotunda lit by the sun at noon and in the afternoon, and heated by vapor circulating . . . beneath the pavement. . . . To the south of the *caldarium* lay the *sudatoria,* whose high temperature induced a perspiration like the hot room of a Turkish bath. Finally the whole gigantic layout was flanked by *panestrae,* themselves backing on recreation rooms, where the naked bathers could indulge in their favorite forms of exercise.
>
> Externally the enormous quadrilateral was flanked by porticos full of shops and crowded with shopkeepers and their customers; inside it enclosed gardens and promenades, stadia and rest rooms, gymnasiums and rooms for massage, even libraries and museums. The

> baths in fact offered the Romans a microcosm of many of the things that make life attractive.[13]

These *thermae* were also miracles of Roman technology that astound the visitor even today. The rooms were enormous and yet, contrary to one's intuitive expectation that such spaces would be drafty and cool, they could be kept extremely warm, even hot. The secret was in the use of a radiant system of heating that could warm a bather regardless of the air temperature. Hot fumes from a great central fire were channeled through hollow tiles within the floor and walls so that the bather was surrounded by surfaces radiating heat. This system was so effective that the baths at Ostia, fifteen miles west of Rome, could be built with great open windows; they were essentially open-air baths. The openings were all oriented to the south to take maximum advantage of solar heating. But even on a cloudy winter's day the heat radiating from the walls and floor was sufficient to maintain bathing, even steam-room, conditions.

The baths were a physical manifestation of the ideal that every Roman citizen was entitled to benefit from the wealth reaped by the empire. Carcopino writes, "In their dazzling marble grandeur the *thermae* were not only the splendid 'Palace of Roman Water,' but above all the palace of the Roman people, such as our democracies dream of today."[14]

Temples in India offer an intriguing example of the conjunction of a thermal place and a sacred place. The great stone temples of southern India, such as those at Madurai and Kancheepurum and many smaller temple towns, provide a sanctuary from the pervasive heat of the tropical climate, where the seasons are sometimes described as hot, hotter, and hottest. A visit to one of these temples will quickly convince the traveler that they are the coolest places to be found in southern India, except, of course, the air-conditioned international tourist hotels. Townspeople and pilgrims come to the tem-

ples for prayer and meditation, but often stay to take an afternoon siesta on the cool stone floors or even to conduct business along the deeply shaded arcades. While the rest of a traditional Hindu town is built of mud and thatch and wood, the use of stone is reserved for temples. It is used for the pyramidal structures that top the shrines (*vimana*) and gateways (*gopurum*) and for the columned halls and long arcades that enclose the sacred compounds. This enormous quantity of stone provides a thermal mass that never reaches the extremes of the air temperatures.

A cool town center, for both sacred and social uses, can be found in the traditions of the ancient Aryans. The villages of the Aryan tribes were centered around a huge tree that "symbolized the axis around which the universe and the celestial realms were believed to rotate."[15] It was in the cool shade of this sacred tree that the village elders met in the *panchayat,* or village council, and it was there that the children were instructed in the sacred texts. This shaded village center grew to include other communal and sacred functions such as a community dancing ground, a local shrine, and, very important, a well or open water tank.[16]

The tradition of the great shade tree as the sacred meeting place at the center of the village may have served as a model for the great stone temples that began to be constructed in the medieval period. Newly powerful Hindu rulers sponsored the building of the temples to form the nuclei of towns. Until the medieval period, Hindus had worshiped primarily at small local shrines and individual altars. These new temple compounds included not only the sacred shrine but the other more communal functions of the traditional Aryan village as well. There was a dancing hall, a temple tank for ritual ablutions, and a deeply shaded place for discussion and teaching of religious texts.

The stoneworking technology necessary for building the temples was late to develop in India. The earliest stone temples were not constructed; they were carved. The chaitya-halls, or prayer halls, of

the Buddhists (ca.250–700 AD) were hewn directly into the face of rock cliffs. At Ajanta, thirty such temple-caves can be found along a single cliff wall. Monasteries were also carved out, using the form of a single-story wooden house built around an atrium, with rooms that open directly onto the court.[17]

The association of caves with religious pursuits is quite common, as Bernard Rudofsky points out: "Faith, piousness, and religiosity of all shading seem to thrive in their padded silence. . . . The basic cavern . . . with its dripping water and bone chilling drafts . . . is supremely qualified to induce a feeling of lightheadedness which furthers meditation."[18] Caves are the stereotypical home of the Christian hermit, along with the Buddhist and Hindu ascetics of India. Innumerable churches were carved into the ground in Ethiopia, Anatolia, southern Italy, and many other areas around the Mediterranean. The distribution of such cave retreats has a clear climatic component, however: they are found only in warm climates where the even temperature of a cave feels cool and comfortable, rather than consistently cold and uncomfortable as in northern caves.

The Buddhist chaitya-halls served as an important prototype for the first southern Indian attempts at stone temples. One early Hindu ruler is reported to have initiated a competition among architects to determine the best form for the Hindu temples that were to be built with the new technology of stone work. Buddhist chaitya-halls and monasteries, in addition to portable wooden shrines and reed-roofed houses, were used as models for the reduced-scale temples that were carved from a single ridge of stone that formed the competition site. These diminutive temples were left half finished, some columns carved in full detail and others left only roughly formed. The most successful model proved to be a square pyramid, a shape that satisfied all the formal, ritual, and cosmological requirements for Hindu wor-

ship.[19] It also effectively placed the sanctuary under a mountain of stone. The earliest temples, such as the shore temple at Mahabilipurum, consisted of this pyramid over the shrine, the *vimana*, surrounded by a low wall. Additional compounds were commonly added later in concentric rings, forming a rectangular mandala, each inner ring being progressively more sacred. With each ring a larger temple gate, or *gopura*, was added. The outermost *gopurum* are enormous and can be seen for miles across the plains.

The temple also included, in its architectural form, the means for being blessed by the four elements—earth, wind, water, and fire. Before entering the temple gates, one removed one's shoes to touch and be blessed by the earth. Then upon passing through the temple gateway, one is blessed by the air with a gust of wind. Villagers believe that the ancients knew how to use the magic of the winds to ensure that there would always be a breeze blowing through the gateway, and in a sense they did. The high pyramids over the gateways catch the slightest breeze aloft, creating a high pressure area that forces a turbulent wind through the narrow passage at ground level, in the same way that American skyscrapers create gusty wind problems at their bases.

A blessing by water is obtained by bathing in the temple tank, or at least descending its steps to touch the water and get a piece of one's garment wet. Finally, on entering the cool interior of the sanctuary, the worshipper is given a mark on the forehead with ashes taken from a small sacred flame by an attendant priest. Even this blessing by fire has a slight cooling sensation to it. Perhaps it is only coincidental that each of these four blessings is associated with a cooling sensation; and yet, the use of forms and materials that inevitably create coolness is quite remarkable.

Some mention should be made here of the role of the temple tanks. Their use is quite ancient, as evidenced by the excavation of

tanks at Mohenjo-daro (ca. 2000 BC). It is presumed that, in addition to serving as a water reserve for the community, they were also used for ritual bathing, a purification rite common in India and many other cultures.[20] Similar tanks are found in India today, both within the temple grounds and along the roadside, often with a large banyan or other tree shading the water and the steps leading down to it, providing a cool wayside stopping place for the traveler. Some of the tanks or wells outside of the temple compounds have a sacred nature of their own. The step-well temple at Adjalaj in the northern Indian desert is an interesting example. The temple-well is built as a series of columned terraces that descend six stories into the ground to meet the variable level of the water table. The well serves as a gathering place for villagers who seek relief from the desert heat. They come to get water and also to worship. Ablutions are performed at each level of the step-well, as the villagers step down to the progressively darker and cooler levels, gradually approaching the water at the bottom.[21]

From these examples—Islamic thrones, Roman *thermae,* Indian stone temples—we can see places whose thermal qualities reinforce their significance within the culture. The thermal qualities may be operating at a level of necessity, like the Roman baths or Indian temples that use collective resources to make basic warmth or coolness available to the whole community. They may employ elements of delight, as do the pleasure pavilions of the sultans or the sensual blessings of the four elements in Indian temples. And they may enhance the attractiveness of a place as a social setting so that, like the Roman baths and Indian temples, they become social centers of the community. In all these ways thermal qualities enrich one's experience of a place and increase its value. Perhaps the simple bodily experience of thermal conditions is sensed as a metaphor for the more abstract meanings represented by a place: the comfort, the delight, the social affinity, each reinforcing the overall significance of the place in people's lives.

The integration of all of these aspects of a thermal place is perhaps most powerfully seen in the tradition of paradise gardens in Islamic countries. Here, the garden or courtyard has a very simple thermal function—to provide cooling with shade and breezes and evaporation from water and vegetation—and has also evolved into a complete metaphorical representation of a people's world view. There are two basic types of Islamic garden. One is the garden in the inner courtyard of a house, such as the famous gardens at the Alhambra in Granada, Spain. The Persian word *bustan* is used to describe these enclosed, formal gardens that constitute a basic formal element of Islamic houses from Spain to India. The second type is not nearly so pervasive but has had an enormous influence on the role of the garden in Islamic culture. It is the palace garden, or rather the *bagh*, an entity comprising palace and garden together.

Both the courtyard and the royal garden have very long histories in the middle east. Their forms are found in the ruins of some of the earliest urban settlements. We know that specially irrigated royal pleasure gardens existed at least as early as the sixth century BC when Cyrus the Great built his palace at Pasargadae in Iraq. Long porticos and a columned pavilion provided shade within the garden compound. A stone water course, with shallow pools at regular intervals, "was clearly the installation of a formal garden."[22]

It is quite understandable that for a desert people the garden became a metaphor for paradise. The Bible mentions the Garden of Eden, the paradise that existed on Earth, as the original home of humankind before the fall from grace. The Koran continued the tradition of Eden, assuming that it would also be our final home in Heaven. "Theirs shall be the gardens of Eden, underneath which rivers flow: therein they shall be adorned with bracelets of gold, and they shall be robed in green garments of silk and brocade, therein re-

clining upon couches—O how excellent a reward! And O, how fair a resting place!''[23]

To provide an image of its promised paradise, the Koran used descriptions of earthly pleasures such as might have been found in the royal pleasure gardens of the time. There shall be ''two gardens, green green pastures, therein two fountains of gushing water, therein fruits, and palm-trees, and pomegranates, therein maidens good and comely . . . houris, cloistered in cool pavilions . . .'' And, ''Therein they shall recline upon couches, therein they shall see neither sun nor bitter cold, near them shall be its shades, and its clusters hang meekly down . . .''[24] In these passages it can be seen that the coolness of shade and water and lush greenery is one of the most essential attributes of this garden paradise. It sounds indeed like the paradise of a desert people.

The Koranic description of paradise became a guide to pattern earthly gardens after. The faithful hoped to create an anticipation of heaven with their gardens, and immodest rulers tried to build themselves a paradise on earth. ''Islamic legend preserves the story of Shaddad, an ancient king of South Arabia, who attempted to rival Paradise by building the Garden of Iram in his kingdom. The story relates that a messenger was sent by God to Shaddad, warning him not to challenge the Almighty. When Shaddad ignored the warning, God destroyed the garden.''[25]

The Koranic descriptions were carefully studied to determine the proper geography of Paradise so that gardens could be laid out in the same form. In one Koranic verse two gardens are mentioned with two fountains of running water, suggesting that paradise was made of two-times-two gardens. A fourfold division of paradise was also suggested by the four rivers mentioned in the book of Genesis that flowed out from Eden. The cruciform division of the garden by four channels of water that meet in the center became traditional

throughout Islam. The significance of this form was reinforced by contact with Persian cosmology, as James Dickie explains:

> In Persian ceramics approximately datable to 4000 BC, the world—represented by a plaque or bowl—appears symmetrically divided into four zones by two axes forming a cross; at the point of intersection a pool is depicted: in other words, there at the focal point of the world the Spring of Life breaks the surface. This iconography, closely connected with the mandala of Buddhist iconography, expresses a vision of the universe, a life-symbol, which, by virtue of its adoption by conquering Arabs, was distributed throughout the entire extent of their empire. In this manner the Iranian garden came to constitute the prototype of the Islamic garden.[26]

While the parallel between celestial paradise and earthly gardens has ancient origins, the poets and religious teachers of medieval Islam were the ones who most elaborated on the metaphor. The Sufis, in particular, were fond of pursuing analogies between nature and the divine. The most benevolent aspects of the weather, the cool breezes and the rain, were identified with either God or the Prophet. The cool breeze was the Breath of God bringing his message of love, as words are carried on the breath of the speaker: "For mystical poets like Rumi, the appearance of the leaves in the spring is caused by their listening to the divine call *Alast*. . . . Moved by this word as manifested in the spring breeze, herbs and flowers come into existence in an en-

raptured dance." Rain is the symbol of Divine Mercy and is even commonly referred to as "mercy" by villagers and peasants.

> The life-bestowing activity of the rain is connected with that of the Prophet of Islam who was sent "as a mercy for the worlds"; hence we can understand the numerous poems which symbolize Muhammed as the "jewel-showering cloud," or as the rain cloud "pregnant from the ocean of love" which slowly wanders from Mecca to Istanbul and Delhi to quicken the dead gardens of the human hearts by his message.[27]

The Sufis especially delighted in using the garden as a metaphor for the human condition. The soil of the garden was identified with the mortality of human beings: "As the dead earth will be resurrected in spring to be adorned with lovely green sprouts and flowers, the dead bones of the true believers will be quickened again as they are allowed to enter paradise."[28] This link between the lives of owner and garden often continued literally after death. While the word *firdaus* stands for both garden and paradise, another word *rauda*, can be used interchangeably for garden and mausoleum.[29] In India there are many grand pavilions that now sit in the midst of barren pieces of ground, empty monuments whose only function is to shelter a sarcophagus. Elaborately carved stone screen-work, patterned marble floors, and airy vaults combine to make them wonderfully cool places. It seems a bit strange that so much effort was expended to provide thermal comfort for a sarcophagus. But at one time each structure was the pleasure pavilion of a king's garden. The Mughuls of India developed a tradition where each ruler commissioned his own garden. Then, "At the owner's death the pavilion, generally placed in the center of the site, became the mausoleum, and the

whole complex passed into the care of holy men."[30] Thus, rather than passing from one generation to the next, the garden remained specifically for the one king. James Dickie writes: "The garden frequently served as a burial-place where the owner, inadequately satisfied with the pleasures it had given him whilst he lived, wanted to continue enjoying them even in death and where—symbolically—he had already entered into Paradise."[31]

The widespread religious imagery of the garden encouraged all owners, royal or common, to regard their gardens with reverence, as a continuing allegory of their relationship to God: as the garden prospered, so did the soul of the inhabitant. In the Sufi metaphor, the body of the owner is seen as the soil of the garden, as the place itself. Similarly, the life processes of the owner were reflected in all of the processes of the garden, not only the plants that grew and died every year but also the water running in channels and fountains, the breezes cooled by shade and evaporation, the sounds and smells of birds and flowers. The life of the garden and the life of the owner were tied together, one as an allegory of the other.

The garden, either as *bagh* or *bustan*, is as central to the concept of an Islamic home as the hearth is to the European home. It is interesting, then, that the hearth-fire in old traditions has a similar association with the life of the inhabitants of the house. Commonly, the fire of the hearth was not allowed to go out. It was carefully covered with ashes each night at curfew so that a few selected embers would survive until morning. (In fact, the word "curfew" originated from the French word for cover-the-fire—*couvre-feu*.) Raglan comments that "the alarm and horror felt if the hearth-fire went out are out of all proportion to the inconvenience caused" by the need to relight it. The fire was ritually extinguished and rekindled only on special occasions usually having to do with the death or, less commonly, the birth of a member of the household.[32] The Catholic Church absorbed this

tradition into Easter ceremonies marking the death and rebirth of Christ: "On Easter Eve, it has been customary in Catholic countries to extinguish all the lights in the churches, and then to make a new fire. . . . At this fire is lit the great Paschal or Easter candle, which is then used to rekindle all the extinguished lights in the church."[33] The symbol of the eternal flame, which we use for our Olympic games and on the graves of presidents, would seem to have had a long history developed from the continuing hearth fire that represented the life and welfare of the residents of the house.

The connection between the life of the fire and the life of the inhabitant is also reflected in the custom of the housewarming ceremony. In contemporary America a housewarming party is given when a family moves into a new house. Perhaps all of the friends and their good wishes are thought to warm the house metaphorically. In traditional cultures, however, the warming is quite literal, for it involves the bringing in, or the first kindling, of the hearth fire, which then creates the proper spirit and sanctity to transform the house into a home:

> In ancient Greece the hearth or *hestia* was the centre of domestic life. At a wedding, fire was carried to the *hestia* in the new home by the bride's mother, thus ensuring the continuity of domestic worship. In India the newly wedded pair formerly brought to their own house a portion of the sacred fire which had witnessed their union and which, when kindled on their own family hearth, had to be maintained ever afterwards for use in all domestic ceremonies, including the last

> ceremony of all, the final burning of their bodies after death. . . . In Wales even now cases are known, when a new household is being started, of carrying fire from the parent hearth.[34]

Aside from a religious rationale, we can easily imagine from our own experience why fire might be used as a symbol of the life of a house and the family that lived there. The fire was certainly the most lifelike element of the house: it consumed food and left behind waste; it could grow and move seemingly by its own will; and it could exhaust itself and die. And most important it was warm, one of the most fundamental qualities that we associate with our own lives. When the fire dies, its remains become cold, just as the body becomes cold when a person dies. Drawing a parallel to the concept of the soul that animates the physical body of the person, the fire, then, is the animating spirit for the body of the house.

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