The Challenge of Creativity – Learning from History?

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Summary

To master the challenges of globalisation ingenious creativity is needed more than ever before. From a historic point of view creativity is a new term in structural engineering. To gain an understanding of the specific creativity of the pioneers in reinforced and prestressed concrete construction it is important to analyse their ability, to develop and cultivate a "creative climate". It was closely connected with some timeless virtues of engineering. Some of these virtues are discussed such as the sense for the material, simplicity, the right balance between static and intuition or the courage to dispute. An important question in this context is the question for the engineer's responsibility. History offers different positions to this. Today, against the background of global challenges, civil engineers have to develop a new understanding of creativity, which is connected with an increased awareness of responsibility and aims at more than structural or aesthetical quality.

Keywords: creativity; globalisation; construction history; reinforced concrete; prestressing; simplicity; responsibility; virtue.

1. Building

Some years ago the Polish journalist Ryszard Kapuscinski, who is an extremely astute eyewitness of the 20th century, wrote an impressive essay called "One day in the life of the world." To agree what we are talking about, when we say "building", I would like to start my lecture with something similar, a short reflection about what engineers, architects and builders are doing day by day, year by year, century by century. Let me start with a brief literary sentence called:

One day of building the world.

One would describe how the sun rises on Paris, New York, St. Petersburg, Singapore. The first ray of light on the top of the Sears Tower, between the pylons of the Humber Bridge, on the cupola of the Florence dome, in the expanse of the Taklamakan desert, where the Chinese at the moment are building a large new road.

One would describe how the native workers are waking up there, their Chinese construction managers, engineers in Rio, project managers in Frankfurt, architects in London, how they are having a shower, are getting dressed – in exactly the way engineers and construction workers are getting dressed all over the world.

A thousand times heavy machines are started, the earth shakes, the air smells of diesel, the first cigarette, others enter their office, start the computer, take a quick look at the e-mail and the post, make the first phone call, phone, again and again they phone, stare at figures, drawings, screens, everywhere screens, in the remotest parts of the globe an infinite net of matte shining machines of knowledge.

One would describe how it is always about dates and deadlines, costs, financial models, how young bicycle couriers with their rolled drawings are wheeling through the gorges of the metropolis, how faxes and e-mail are being sent high up to a satellite in order to reach the addressee just a stone's throw away in a matter of seconds, how standards committees assemble, conferences and workshops convene, and all they write, publish, produce a lot of paper with a lot of symbols, you could think they are aiming to build towers of paper, not buildings and structures.

Midday. Rice and a cup of green tea in the shadow, wine and carpaccio in the club, or just a sandwich. Later thousandfold ventilators try to soothe the heat in the afternoon.

And One would describe the night, closing time, the grey tiredness after the pains of the day, the shadows of darkness, snatches of music, burning oil barrels, campfires, neon lights. Would tell how they lay down to sleep, in the suburbs, in shabby flats, in containers, in tents, in cheap hotels – some with figures yet in their heads that cannot be put together, some who don't know how to manage tomorrow, some who don't know whether they will find work the next day.

Outside, in the building pit, the pumps restrain the ground water, the pile driver screeches, high above welders marked by bright light spots perform their night shift on the steel frame.

One day of a huge machine of mankind, counting millions, that day after day scrapes on the tender skin of this planet, rakes up the earth, piles it up, always new, sometimes nicer, a machine of mankind, at the same time building, planning, constructing, calculating, controlling, financing.

One day of building the world.

2. Creativity

This is the background, against which we are thinking about "creativity". It is called globalisation.

Millions of people, millions of practices, millions of voices. Ever becoming more similar. Faster than ever differences, peculiarities, cultures, developed over millennia, disappear. Faster than ever diversity on this planet shrivels - cultural as well as biological. In 2003 the World Wide Fund for Nature has classified, in its so-called Red list, 12.250 species as highly endangered. Globalisation can be characterized as well by using a term which is more familiar to engineers: entropy, the process of an irreversible mixing to lower levels of order.

Day after day we, the engineers, are part of this global process. The off-shore stations which we erect actually destroy the natural habitats of the last 150 grey whales near the Japanese coast. The great dams which we have optimised drown the religious heritage of centuries behind them. The innovative bridges which we design, have meanwhile brought new roads to nearly every valley of the Alps and robbed the landscape of its beauty and tranquillity. Engineers build up, engineers destroy.

Isn't it absurd when engineers from all over the world come together in a extremely precious historic palace to reflect about „The Challenge of Creativity" against a background, in which they themselves are precisely the ones who provide the means to mankind to destroy, day after day, faster and more effectively the diversity and plenty of this apparently extremely rare planet called earth? Have we not to face up the fact that there are other types of „challenges", totally different and much more important?

Yes – and no. Perhaps more than ever before ingenious creativity is needed. Precisely because, in the course of globalisation, the individual seems to become unimportant, precisely because challenges have become greater than ever before, and also because the civil engineer's products of today - buildings, roads, structures and systems - go beyond the benchmarks we are familiar with from history, precisely for these reasons we as the engineers of the 21st century are nearly obliged to search with extraordinary diligence and prudence for appropriate, creative solutions and answers.

Nevertheless we should be careful. Creativity – the term seems to be a little too popular at the moment. The term is booming inflationary. Every second important speech of European politicians calls for creativity to achieve economical salvation, advertising agencies promote everything as creative, and last but not least, coming to the field of civil engineering, books and articles about the "art of the engineer", "creativity and innovation", "bridging the gap" and so on have become innumerable.

What does it mean – creativity in engineering? The engineer's creativity and ability to innovate is poorly understood.

Bill Addis characterised it as a "combination of inspiration and logic."[1] But – why don't we try to "bridge the gap" and ask literature? In 1933 Paul Valery (1871-1945), the famous French author and philosopher - a contemporary of Freyssinet, Maillart and the others - published some fascinating studies on Leonardo da Vinci. In the first one of these essays called "Introduction à la

méthode de Léonard da Vinci", written in 1894, Valery, using Leonardo as an example, aims to describe, to develop - or better – to construct the ideal of a genius, the epitome of creativity par excellence. For him the „mystery of Leonardo" lies in his ability, to find "relations (…) between things, which are not apparent by logical continuity." [2, p.16] According to Valery creativity accrues from the „pleasures of construction". Creativity means „to awake from the sleep of a mode of thinking, which has lasted too long." [2, p.18]

Creativity for him is connected inseparably with visions: „One who never has ventured to the adventure of constructing (…), one who never has seen an image on the blank white of the page (…), one who never has caught sight of a building not built yet in light empty space, one who never has felt vertigo in face of distance from his aim (..), does not know the richness and the fruitfulness and the mental span that enlightens the act of constructing." [2, p.40]

3. History

History of building with reinforced concrete is most suitable to search for the parameters of creativity, precisely because its pioneers had to overcome so many resistances. An inconsistent material made of antithetic materials - not only at French Grands Écoles it was eyed extremely sceptically. A report of the official Prussian periodical „Centralblatt der Bauverwaltung" concerning Monier's ideas culminated yet 1886 in the result: „From the outset it is absolutely improbable, that the iron and the cement come to the same bearing" [3], and Augustin Mesnager confronted Eugène Freyssinet with the simple conclusion: „*Vos résultats ne sont pas seulement faux; ils sont impossibles*". [4] „Invented by a peasant, Louis Lambot, patented by a gardener, Joseph Monier, both in fact interested primarily in a non-rottable substitute for wood, developed by a bricklayer, Francois Hennebique, who on his part just looked for a fire-proof substitute for wood: This could not be a material for serious engineers. [5]. Those who nevertheless embraced it had to have a lot of fantasy and - creativity.

Let us immerse into their time. Let us juxtapose some of our heroes in a virtual room and ask them: What is creativity?

Many of them have given to us a lot of recommendations for being a good engineer. I could remind you of papers and writings of Fritz Leonhard, of Eduardo Torroja, of Pier-Luigi Nervi – or, for example, Eugène Freyssinet: „*Les qualités de caractère – courage, probité, amour et respect de la tâche acceptée – sont infiniment plus nécessaires à l'ingénieur que celles de l'intelligence qui n'est jamais qu'un outil aux ordres de l'être moral*." [6, p.100]

What about creativity? First observation: We call them „creative", but for most of them obviously the term was foreign. They did not use it perhaps they did not even know it in this context. Creativity is a quite young word in the language of structural engineering.

We have to look for the parameters of their creativity, less interested in "What?" was built but "How?" or "In which way?" it was designed. Modern science history prefers to pick practises out as its central themes, aims not the products but the processes of constructing. To gather an imagination of creativity the best way is to explore the facets of the philosophy of approach that make "creative".

Let us dare to speak of "virtues", this old-fashioned word. The dictionary defines them as "ideal types and images of personal excellence". According to the philosopher Hans Jonas, virtues project "the best possible being of human beings." [7] Perhaps I like the term virtue because it alludes to tradition and something old. Virtue is directed towards future as well as to origin.

Let me point out in quick succession only a few of these virtues of the engineers that possibly have led them on their way to ingenious creativity.

3.1. Listen to the materials

The whole history of reinforced and prestressed concrete construction is a history of precise listening to the materials. Not until the use of high tensile prestressing wire the full potential of the different materials is tapped.

That is the reason, why Dischinger's „Adolf-Hitler-Brücke" across the river Mulde in Aue, erected 1936-37, was a less intelligent prestressed concrete structure than Freyssinet's bridges across the Allier River near Le Veurdre, erected nearly 30 years before. The normal construction steel St 52

that Dischinger had used fort he tendons, was as inadequate as the rather poor concrete. Dischinger did not use, what steel is able to and must provide in a strange combination like this. Meanwhile Freyssinet, to fix the abutments of his bridges, yet 1907 chose a concrete tie of 1.5 m^2 in cross-section prestressed with some hundred cold-drawn wires of 8 mm in diameter, stressed close to their limit of elasticity. Some four decades later, in 1949 he could write: "Conceived in 1907 and executed in 1908, this tie was the ancestor of all prestressed structures" [6, p.109]

It was Eduardo Torroja, who complained in an impressive way, how difficult it seems to be for modern engineers, to design, or better: to think appropriate for the materials involved: „Our capacity to develop the aesthetic quality of structural harmony, in terms of different materials and its structural requirements, is as undeveloped in our time as orchestration and counterpoint were in the seventeenth century. The reason is possibly the spiritual divorce of our specialized techniques." [1, p.11]. It is a great challenge to rethink the way we can use materials.

3.2. Simplicity

Simplicity in this context implies the greatest simplicity possible as a primary criterion for optimisation. Simplicity of approach should be regarded highly especially today when a sophisticated calculation technique tends to seduce us into believing we can somehow calculate everything. The best among the engineers have always known about simplicity.

Think of Eugène Freyssinet, best schooled at the École Polytechnique, who nevertheless again and again emphasized that a different training had shaped his engineering far more than his formal education, namely, his roots in the crafts. In the end, this helped him find simple solutions. According to Freyssinet one of the most important things for the engineer is „*un souci extrême de la simplification des formes et de l'économie des moyens*." [8, p.17]

Especially in reinforced and prestressed concrete construction it is difficult to think and design in a simple way – too conflictive seem to be the components of structure. From a historic point of view as well for a deeper understanding of what happens in concrete structures it is quite remarkable, that the structural concept of reinforced and especially prestressed concrete is a concept of superimposing different elementary structures, Even this is exactly the bridge building concept of Baroque engineers. Think for example of Hans Ulrich Grubenmann's famous Schaffhausen-Bridge across the Rhine, erected 1756-1758: Its structural concept is based on the overlapping of different structures, arch frames with inclined struts as well as multiple queen-post trusses [9]. There is not much of a difference to the structural idea of prestressing concrete. We see an identical structural philosophy. It aims to increase and optimise the load bearing capacity of a structure by overlapping different structures.

At the beginning of the 20th century a structural thinking like this was strictly opposed to the mainstream of structural philosophy. The latter had characterised and dominated the whole process of creating the language of building with steel in the course of 19th century; it aimed to understand and optimise structures by analysis, reduction and segmentation – by the way closely connected with the ideals of enlightenment in cultural sciences. Presumably it is not by accident, that this new, old structural philosophy started to achieve acceptance in even that time, in which physics quit the „simple" mechanical world view of Isaac Newton. And possibly this interpretation of the idea of pretension as a deep change of paradigms in structural philosophy may get across the huge scepticism, the pioneers of it have been confronted with.

The striving for structures as simple as possible, again and again recommended by many heroes of construction history, certainly must be regarded as a key to creativity - but simplicity in reinforced and prestressed concrete is e difficult thing.

3.3. Sensibility and intuition

Sensibility and engineering – for many engineers this is a classical antagonism.

Let us return once again to Paul Valéry, who has given also to this facet of creativity an poetic expression. In his dialogue „Eupalinos ou l'Architecte" Socrates meets Phaidros – intellect meets sensibility. The latter reports to Socrates of a friend of him, Eupalinos, a Greek builder, architect as well as engineer, who must have been a fascinating personality. He was capable to understand and

design buildings and structures with deep sensibility – as in his own words, "a dream, not science". While he built, he built himself. „It seems to me my own body is always involved." [10]

Are there any connections to pretension and concrete construction? Yes. Think of Candela, think of Freyssinet, when he affirms: „*Je suis un intuitif, beaucoup moins soumis à sa raison qu'aux impulsions de son subconscient, un survivant d'une race d'artisans aux instincts constructifs formés par des millénaires d'isolement dans des conditions de vie particulièrement dures.*" [8, p.17]

Sensibility and intuition underline the subjective character of every design. After having finished in 1951 his first hyperbolic paraboloid, the little pavilion for cosmic radiation research in Mexico-City, a shell structure that should make him a famous man, Felix Candela began, "to sense, that I had my own opinion. Before I never had dared to have an own opinion". [11]

For him there was no gap between this strong claim for intuition and the subjective aspects of design and his enthusiastic love to mathematics and static analysis.

3.4. Modesty, poverty

Candela develops his first shell structures in a poor Mexican village. Freyssinet's concept of prestressing matures in the time of his deepest crisis. 1929 he just had to resign from office as director of Limousin. A man of 50 years, alone with his „hopeless idea" of prestressing, he has to face the thread of economical ruin. It takes more than four critical years until 1933, when he finally can find a first licensee, the company Forclum, to develop a new type of - prestressed - powerline pylons, but the expected economic success fails to appear; against the background of the persistent economic depression Forclum can not sell more than a few thousand of its pylons. The production line is for scrap and Freyssinet again is near bankrupt [5, p. 18].

Nevertheless even in those years of solitude he develops idea and principles of prestressing, theoretically as well as practically. 1934 will bring him to his first great success, the consolidation of the Le Havre landing station for SS Normandie, the largest passenger ship of its time. The concrete pile grid of the station is settling uncontrollably into a layer of mud, which hasn't been noticed by the engineers before. Freyssinet proposes the consolidation of the structure with a completely novel and untried prestressing method, combined with a lot of other techniques which has yet to be fully developed. Some twenty years later he will write: „*Aurais-je eu le courage de prendre la responsabilité de ce projet ...* - Would I have had the courage to accept the responsibility for this structure, had it not been the only chance to save my invention from oblivion? It had cost me all my fortune and five years of extreme hardship; above all Le Havre seemed to be the only chance to regain confidence in myself and my work." [5, p.18]

The crisis as impetus for creativity. The history of creativity in many parts seems to be a story of poverty and insufficiency - insufficient materials, insufficient experience, insufficient infrastructure. Out of insufficiency arose the engineers' special quality. Out of insufficiency he forces to take upon the smallest details, out of insufficiency he has to develop clear and highly economic solutions. Due to insufficiency he is able to enrich the international language of structural engineering in his own way.

Poverty and modesty as an impetus for creativity – a phenomenon that we can find as well in many fields of culture beyond technical disciplines. I just want to remind you of the outstanding quality of the architecture of Karl Friedrich Schinkel. First of all this is due to its enforced modesty, resulting from the specific culture of poverty that was characteristic to Prussia as an extremely poor country in Schinkel's time, the early 19th century.

3.5. Courage to Design and Dispute

Another virtue may be recalled just for a minute: courage. The confession of originality, of the autonomy of the engineer implies courage. And courage implies a readiness for criticism and to dispute; with that, in particular, engineers have an exceptionally hard time. Let's have a look at our construction periodicals: when do we come across a productive argument or an intelligent discourse? Isolated engineers write their texts into a void - unanswered, without dialogue, a silence lasting many pages. True disputes are extremly rare.

Especially here, the history of construction technique offers a multitude of model cases. Let us only remain at the pioneers of reinforced concrete. Take just Robert Maillart. He was capable of developing and realizing load-bearing structures and shapes, which impressively grew out of structure and material. They appeared strange at first to his era. Individual, subjective designs as they were, yet today they are easy to identify as "Maillarts bridges". But Maillart was not only courageous in design. His attacks against "applied-science engineering" or against the introduction of new Swiss codes, which he called "Paragraphenpanzer", are as impressive as his famous debate with the German architect Paul Bonatz about bridge design, when he "urged engineers on their own to think deeply about aesthetics (…)". [12]

Such courage to design requires a schooling of the eye, aside from a high level of constructive competency, and it implies a healthy measure of self-esteem. I cannot help the impression that there is a greater lack of both today than there was one hundred years ago.

3.6. Responsibility

When speaking about responsibility, engineers first of all think about the immediate responsibility for the secure technical success of the building. But taking responsibility had a different air about it at different times, especially in periods of history, when pioneers start to construct and build with previously almost unknown materials. In "open" eras like these they have to build into a vacuum of material science, measuring theories, technical rules, regulations and norms. None of that exists. Instead, there is a spirit of departure, courage, delight and cunning and the prospect of great transactions. The engineer is liable for the success of his work from head to toe, often with an immediate financial involvement in his projects. We know this specific ethic of responsibility from the icons of 19th century British engineering as for example Isambard Kingdom Brunel, and we can find something very similar at the pioneers of reinforced concrete. To be liable with body and soul for one's work - think of Felix Candela, think of Freyssinet, who had to take nearly physical responsibility for success or failure of some of his bridges at the beginning, technical as well as economical. Obviously there is a close and fruitful relation between liability and the need of creativity.

Nevertheless beyond responsibility in the sense of liability, another aspect of the term has to be considered. We cannot get around defining it in the sense of a „*responsabilité morale*", as did de Lalande, the responsibility, in the sense of the duty of humans as reasonable beings, to confront the positive or negative evaluation of our deeds. The philosopher Hans Jonas dedicated himself to this topic in his writing "Das Prinzip Verantwortung" (The Responsibility Principle) [7]. Explicitly he pointed out that today virtues alone are no longer sufficient. Precisely because our present deeds cast shadows into the future that are longer than ever before, we require a far-reaching principle, directed towards the future.

Does the awareness of „*responsabilité morale*", the conviction of a far-reaching principle of responsibility encourage ingenious creativity? Does it stimulate the engineer's search for new solutions and innovation? Obviously the history of concrete construction offers different answers and different personal attitudes. An extremely interesting period in this context is the 1930s and early 1940s, the time of National Socialism and Fascism in Europe. The relations of the pioneers of concrete construction to the dictatorships possibly can be regarded as exemplary for their ideas of responsibility. The young Felix Candela went into exile to Mexico, Maillart partly opposed from Switzerland, others as for example Franz Dischinger or the young Fritz Leonhard have been extremely successful in close cooperation with the "Third Reich"- Officials. And since the publication of Grote and Marrey [5] some years ago we have to note, that even Freyssinet apparently had a broken relation to collaboration.

In the 1950s Freyssinet formulated his personal position to responsibility in a wider sense. According to him the engineer is strictly obliged to confirm the reliability of his assumptions, but on the other hand "*L'ingénieur a le droit d'ignorer tout ce qu'il n'utilise pas*" – the engineer has the right to ignore everything not of use for him. [8, p.128]. Fritz Leonhard after 1945 held a strictly contrary view. In many cases he took up clear position in public debates of after war Germany, so in 1956, when he courageously argued against the German rearmament and called the engineers in general to refuse every service for war, [13] or in 1981, when he gave a lecture about the problem of the builder's responsibility for the society. [14]

Do we need a moral to be creative? Obviously this is a complex problem, a question to difficult to answer in a minute. History is not what we want it to be. Perhaps for the moment we should change the question, and the answer: Engineers need a lot of ingenious creativity, if they want to take their part of responsibility for the future of this planet.

4. Outlook

To master the challenges of globalisation we need ingenious creativity more then ever before. From a historic point of view it is an absolutely new term in engineering. The reason that we call some of the pioneers in reinforced and prestressed concrete construction "highly creative", lies in their ability to develop and cultivate a climate, a philosophy of engineering, which was connected with some timeless virtues such as the sense for the material, simplicity, the right balance between static and intuition or the courage to dispute. Some others could be mentioned as a sense of tangible clarity, care in detail or the ability to communicate.

Compared with those of the beginning era of reinforced concrete the challenges for civil engineers have changed. The answers must change too. It is important to develop a new understanding of creativity, which does not wear out in searching for structural or aesthetic quality.

Every generation of civil engineers has to decide how to construct themselves to become creative builders of the future again. To develop and advance a climate of creativity, we should not be afraid to revive some traditional virtues. And we should try to formulate - and to teach how to live by - credible answers to the question of responsibility of today's engineer. We should find the courage not only to help young students to understand the mysteries of load bearing, composite materials, soil mechanics or construction management, but - beyond all fatigue- and life-span projections - allow and satisfy their hunger for infinity. Then we could succeed. As is the case with every serious revision, this implies willingness to question everything, our seemingly self-evident paradigms as well as our seemingly self-evident practices.

Leon Battista Alberti comes to mind, the legendary uomo universale of the Renaissance about whose far-reaching interests and abilities wondrous things have been reported. He was not only an architect and author of "De Re Aedificatoria" but also a mathematician, physicist and jurist. A very sensitive as well as successful person: the view of splendid trees brought him to tears. His imperative was "humans can do everything if only they want to." Maybe Alberti's most noble virtue lies in his playfulness. In the depth of an antique bookstore, I recently came across a book wondrously titled, very similar to Paul Valéry: "The Existential Pleasures of Engineering" [15]. Yes indeed, the pleasure of being an engineer, the pleasures of construction! Traces will be left only by those who build with their hearts. To sum it up, this means not more and not less than to redefine ingenious building again, and always anew, as a cultural task and to define ourselves, the civil engineers, as the proper elite responsible for it.

5. References

[1] ADDIS B., *Creativity and Innovation. The structural engineer's contribution to design.* Architectural Press, Oxford e.a., 2001,138 pp.

[2] VALÉRY P., „Introduction à la méthode de Léonard da Vinci", written 1894, first published 1933. German translation in: *Leonardo da Vinci. Essays.* Suhrkamp, Frankfurt am Main, 1998, pp. 7-61.

[3] Z., „Monier's Herstellung von Baustücken aus Cementmörtel mit Drahteinlagen." *Centralblatt der Bauverwaltung.* Vol. 6, 1886, p.88.

[4] BOSC J.L. e.a., *Joseph Monier et la naissance du ciment armé.* Éditions du Linteau, Paris, 2001. p. 9.

[5] GROTE J., MARREY B., *Freyssinet, la précontrainte et l'Europe.* Éditions du Linteau, Paris, 2000, 111 pp.

[6] MARREY B., *Écrits d'ingénieurs,* Éditions du Linteau, Paris, 2000. 180 pp.

[7] JONAS H., *Das Prinzip Verantwortung.* Insel-Verlag, Frankfurt am Main, 1979.

[8] FREYSSINET E., *Un amour sans limite.* Éditions du Linteau, Paris, 1993, 189 pp.

[9] LAFRANCHI, M., DE GIORGI, P., „Some remarks on the Grubenmanns' wooden bridge structures". In: MAGGI A., NAVONE N. (Ed.), *John Soane and the wooden bridges of Switzerland*, Archivio del Moderno, Mendrisio 2003, pp. 114-135.

[10] VALÉRY P., "Eupalinos ou l'Architecte". First published 1921. German Translation by Rainer Maria Rilke, in: BLÜHER K. (Ed.), *Paul Valéry, Vol. 2, Dialoge und Theater.* Insel Verlag, Frankfurt am Main 1990, pp. 7-85; pp. 26, 21, 29.

[11] FABER C., *Candela und seine Schalen.* Calwey, München 1965, p. 41

[12] BILLINGTON D., *Robert Maillart. Buider, designer, and artist.* Cambridge University Press, Cambridge 1979, p.216.

[13] LEONHARD F., „Haben militärische Mittel noch Sinn und Wert?", in: LEONHARD F., *Baumeister in einer umwälzenden Zeit.* DVA, Stuttgart, 1984, pp. 309-312.

[14] LEONHARD F., „Bauen in der Verantwortung vor der Gesellschaft", ebd. pp. 313-320.

[15] FLORMAN S.C., *The Existential Pleasures of Engineering*. St. Martin's Press, New York 1976.