On the Mode of Existence of Technical Objects

by

Gilbert Simondon

Paris: Aubier, Editions Montaigne, 1958

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June 1980

Work on this project was supported through
the Explorations Program of The Canada Council

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PREFACE

by

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Simondon's doctoral thesis, of which the English translation of Part I is given here, has a two-fold value, firstly for reasons implicit in the initial recognition it received two decades ago, and secondly for its relevance in connection with themes which have since become more evident. Slow as it has been to obtain the recognition it deserves, the book received attention originally as an introduction to a new way of understanding technology. As a scholarly work explaining the humanity contained in the machine, there was nothing like it in the entire philosophical corpus devoted to the machine, nothing that is, which combined a philosophical treatment with the same proximity to the technical object. The outstanding quality of Simondon's treatment is that for all the difficulties of crossing separated domains of meaning his writing is essentially, deep down, a work of praise. When, at the second mechanology conference, he commended the Coal Board of England for the restoration of a Newcomen Engine, he observed that the objective of conservatories and museums is to put technical objects back into working condition. "There is," he said "something eternal in a technical schema . . . And it is that (quality) which is always present and which can be conserved in a thing."[1] The only other writer who placed the technical object on the same high plane was Jacques Lafitte whose book published in 1932 first recommended the establishment of a science of machines or mechanology.[2]

If as I believe, this translation is associated with a second moment in the emergence of mechanology, it nonetheless responds still to the exigencies of the first. We may envisage a new group of readers, not necessarily distinct but encorporating interests which did not exist before. The first group were scholars and professionals in the social sciences; for them mechanology is a much needed discourse on technics, which is to say, a scientific treatment having technical operations as object. The new group would be those who, anticipated by the author, perceive the possibility of encorporating the machine into the family of things human as part of a global cultural rennaissance.

Between the earlier and later presentations of the technological object there is no incompatability. As occidental technology expands throughout the world, reflection on its meaning must reach down past contradictions into

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[1] G. Simondon, in Cahiers du Centre Cultural Canadien - No. 4, Deuxieme Colloque Sur la Mecanologie, Paris, 1976, p. 87.

[2] J. Lafitte, Reflexions sur la science des machines, Bloud et Gay, Paris, 1932.

the most fundamental, most universal intentions independent of ethnic roots and national cultures. The creative flowering of some part of human expression is not necessarily confining or restricting. But technological creativity is confining unless it is allied with other human aspirations. Technical objects alienate unless they are somehow baptized, that is, unless they become attached to intentions which respond to the contemporary level of the highest human hope. It is value which gives technical creativity its currency, its transcendance in view of communication, adding to praise the essential quality of the gift.

Referring to the need for quality (i.e. value) Persig gives the example of a couple whose attitude toward a broken motorcycle or a leaking faucet alternated between outright hostility and apparent unconcern. He discovered that the unconcern was a mask for suppressed anger, held back because to reveal it would be to give technology too much importance. He concluded that it was not the motorcycle maintenance, nor the faucet repair nor any other annoyance or malfunction but the whole of technology which is the enemy.[1] The individual machine or machine element becomes a distasteful symbol for the entire dehumanized world, best symbolized by the barbed wire fence around

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[1]R.M. Persig, Zen and the Art of Motorcycle Maintenance, Bantam, New York, 1975, p. 15.

a factory. Persig says that he is sensitive to the host of dehumanizing influences. He disagrees with the couple about cycle maintenance, "not becuase I am out of sympathy with their feelings about technology. I just think their flight from and hatred of technology is self-defeating. The Buddha, the Godhead, resides quite as comfortably in the circuits of a digital computer or the gears of a cycle as he does at the top of a mountain or in the petals of a flower. To think otherwise is to demean the Buddha, which is to demean oneself."[1]

In actual fact, the group of people envisaged in this second moment of mechanology scarcely exists. They are people possessed of the idea that the machine is in a sense separate but not necessarily divorced from value. Knowing that it arises out of a pure Dionysian aspiration, capable of existing in radical isolation from other aspects of life, and that alongside it, alongside its mechanology there must exist what Daly calls a metaethics, awareness of value beyond the current perception of humanity, advancing together with it in a process of convergence.[2]

Before making the jump to the new possibilities, let

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[1]Ibid., p. 18.

[2]M. Daly, Gynecology; the Metaethics of Radical Feminism, Beacon Press, Boston, 1978.

us consider the way Simondon's work was perceived in 1958. The French edition is in three parts, corresponding to three modes of existence of the technological object. Part I, entitled Genesis and Evolution of Technical Objects, is devoted to intrinsic machine reality, to the principles and corresponding examples of the nature of the technical object. Part II is called Man and the Technical Object. It may be considered commentary, in the light of mechanology, of the work of Wiener: Human Use of Human Beings.[1] The concept of information, the nature of progress, the meaning of automation and other derivatives of the scientific and engineering applications of thermodynamics are important themes. Part III is called Genesis of Technicality. If Part I may be said to be devoted to the machine itself, its intrinsic structure and evolution, and Part II to the man-machine relationship, Part III is essentially an essay on the machine and philosophy. In it the author expands on the idea that philosophical thought, in order to seize the significance of the existence of technical objects, must be directed to the existential situation of these objects and to the conditions of their genesis arising out of the relationship between humanity and the world.

In attempting to introduce the ideas of Simondon, I

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[1] N. Wiener, Human Use of Human Beings: Cybernetics and Society, Houghton and Mufflin, Boston, 1950.

am faced with a task similar to his when he organized a conference in the series of international colloquia at Royamount in 1964, devoted to cybernetics and featuring Wiener as key speaker. Simondon was called upon to provide the context in which the assembled philosophers and scientists might hear what the founder of cybernetics had to say on the topic and title of the proceedings: The Concept of Information in Contemporary Science. Referring to the fact that cybernetics grew out of the reflections of a group of scientists at MIT (mathematicians, biologists, physiologists, etc.) he compared it to the work of Newton, the last man of science to cover the entire domain of objective reflection, and went on to say, "In fact, historically, cybernetics appeared as something new directed to achieving a synthesis; in sum, we find ourselves brought back to the time of Newton, or to the time when the great philosophers were mathematicians or scientists in the natural sciences and inversely. This is doubtless the context in which it is now possible to listen to what Professor Wiener has to present to us."[1]

A resurgence of interest in Simondon's main themes

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[1] G. Simondon, introduction of Norbert Wiener in Le Concept de l'information dans la science contemporaine, Les Cahiers do Royaumont, Collection Internationale sous la direction de M. Louis Couffignal, Gautier-Villars, Paris, 1965, p. 99.

would show up the contrast between the scientific philosophy of cybernetics and mechanology. Mechanology is not, like Wiener's cybernetics, a kind of successor to the natural philosophy of Newton, but, insofar as the parallel is valid, a successor to the Anatomia Universalis of Harvey.[1] Whereas the central notion of cybernetics was system, the comparable concept in mechanology is soma. It is the human body with its balance, its rapport, and its emanations which gives to mechanology a degree of universality which put it into legitimate comparison with the broad extension of science. Although this reference to the body is not explicit in Simondon, the new importance attached to his ideas may be seen to arise because of the contribution they make to this perspective.

The synthesis which cybernetics attempted, often described as a new crossroads of science, was very instructive both in how it failed and how it succeeded. Using Kuhn's terminology, it was the locus of a paradigm change which, insofar as science was concerned, was both a check and a balance, a constraint and a renewal.[2] Science was directed toward new and fresh paths while being

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[1]W. Harvey, The Anatomical Lectures of William Harvey, G. Whitteridge, Ed., E. & S. Livingstone, Edinburgh, 1964.

[2]T.S. Kuhn, The Structure of Scientific Revolutions, University of Chicago Press, Chicago, 1962.

cautioned to abandon its Promethean ambition. Cybernetics had begun with a plea to return to interdisciplinary studies, to turn away from narrow fragmentation to a mode of perception like that of Newton's. In the best minds, that is what happened. The cybernetic concepts of feedback and information began to reach out across the natural sciences and include the social sciences as well. At the same time, computer and information science was recognized as a welcome newcomer since its independent investigations of informatics and algorithmics were found to be valuable in the other sciences. Finally, in a dramatic extension beyond previously charted domains of investigation, the study of Artificial Intelligence of and with the aid of machines opened vast horizons for objective, scientific investigation.

These projects were all lateral horizontal expansions, the legitimate reproduction in kind of the domain of objective investigation. At the same time the overweening ambition of science since long before Newton which gave science its vertical ascension was terminated, probably never to return. Science, meaning the entire domain of objective investigation, had become the Procrustian measure of knowledge. Its proponents made it into a kind of belief system, or at least the prominent half of the two intellectual cultures, Arts and Science.

Cybernetics, in its short career as synthesis or umbrella of science, was driven by the same imperialism. At the Royaumont Conference, one of the speakers, François Bonsack, attempting to describe information as something to be sought for its own sake and as component of finalized action, refers to the crucial study of Ruyer devoted to the problem of defining information independent of consciousness.[1] In his book on cybernetics and the origin of information, Ruyer questions the absence in cybernetics of an axiology, that is, of a reference to value. He asserts that what is omitted from all of the mechanistic explanations are the "values or valences controlling actions by a kind of axiological feedback analogous, but not reducible to the mechanical feedback of automata".[2] Classical science and technology had begun to recognize the insufficiency of a scientific speculation from which value is absent in the explosive dangers of excessive productivity: nuclear armament, automobile pollutants, industrial waste, agricultural practice. Ruyer, looking at the intrinsic development of science as it dealt with the concept of information, picks the precise moment where a notion of value is excluded. In doing so he was bringing to bear the radical departure of

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[1] Ibid., p. 321.

[2] R. Ruyer, La Cybernetique et l'origine de l'information, Flammarion, Paris, 1954.

contemporary European thought insofar as it owed its basis to classical Greek culture. As expressed in the phenomenology of Husserl and others, this departure began by denying that science has a preferential situation with respect to the reality which surrounds human life. The crystalization and perhaps the most decisive moment of this revolutionary mode of thought is given in Max Scheler, a student of Husserl, in his doctoral thesis at Jena in 1897. This thesis attacked the rationalistic basis of all that is implied in the Nicomachean Ethics of Aristotle and stated in effect that ethical principles and logical principles belong to different domains of meaning.[1]

Around the machine circle the main themes of our age: technology is implicit in their causes as well as being an element in their evolution. But since cybernetics has suffered a check to becoming the means of understanding that technology, where can we turn? If science and its associated philosophy cannot do so because its basis in natural philosophy is not suitable, can we call upon a mechanology invented precisely to bring the meaning of that reality in contact with other domains of knowledge? We

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[1]M. Scheler, Beitrage zur Feststellung der Beziehungen zwischen den Logischen und Ethischen Prinzipien, Jena, 1897. The most accessible introduction to Scheler's ethics of values is given in his book The Nature of Sympathy, tr. by Peter Heath, New Haven, 1954.

run here into a obstacle which has not to do with appropriateness but to the fact that Simondon's thesis (and Lafitte's) is presented in a language which is by and large inaccessible to most readers.

Simondon is not unaware of the terminological difficulties. He attempted to rectify the inadequacies of the written word with diagrams better able to illustrate technological function and composition. The first edition was published without these diagrams, an omission by the publisher due to cost but significant for other reasons. Without this non-verbal presentation, deemed essential,[1] the book as it first appeared in the Analyse et Raison collection of Aubier, bore the stamp and manner of a philosophical study. The presentation implied that the work was to be seen, as it had been launched, among the progeny of the familiar French philosophical tradition, rather than a radical departure. When the book appeared in 1958 it was nonetheless well received. Typical of its recognition was the reference to it in Volume 110 of Cahiers de l'I.S.E.A. (1964) devoted to 'Progress', after it appeared. Considered as "a solid and brilliant essay on the technical object,"[2] it is praised as a philosophical

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[1] See the defence of non-verbal thinking and non-scientific modes of thought in E. S. Ferguson, The Mind's Eye: Non-verbal Thought in Technology, Science, Vol. 197, August 1977, pp. 827-836.

[2] G. Granger, in Le Progress, Cahiers de l'Institut de Science Economique Applique N 110, Fevrier 1961, p. 23.

investigation in which the modalities of progress are described. It is noted that "the perfectioning proper to technology consists in passing from the 'abstract' machine to the 'concrete' machine wherein the organs are more or less integrated into the whole. The antagonisms and reciprocal limitations are progressively effaced, the functioning of the machine tending to become a global functioning, and in sum, the technological object approaches the natural object but by other ways than those of nature."[1] Valorizing the same theme and making it more important, van Lier, in 'Le Nouvel Age', a book devoted to the new chances of humanism, proposes that "this new visage (of the machine) explains or in any case reinforces most of the essential characteristics of the contemporary world; that it suggests a system of values suceptible of promoting a new humanism."[2]

And yet, although the reviews and commentaries were favorable, it has not happened that the intrinsic nature of the machine according to Simondon has become part and parcel of contemporary technical discourse and indeed is not as well known as the majority of thoughtful works appearing at the same time or later. The reason for this,

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[1] Ibid.

[2] H. van Lier, Le Nouvel Age, Casterman, Tournai, 1964.

though creditable somewhat to the special optic of the social scientists, philosophers and literary critics who signaled its advent, is that the language in which mechanology is written is an obstacle for all but the rare individuals in whom there is a combination of scholarly and mechanological experience, enabling them to bridge the gap between domains of meaning which until now have been separated.

Consider the concept which has been recognized as key. In this translation we have allowed the word 'concrétude' to be translated as 'concretisation' knowing that the true sense of machine genesis is thereby lost. The equivalent in English of the mechanological meaning is closer to 'concrescense' but it too is inadequate. What we are dealing with is a non-pejorative but distanced mode of expression; it is latin in origin and choice of sense, with consequent distance between the real machine and our conception. This usage and that of the corresponding antonym, abstract, is not an isolated phenomenon; nor is it indifferent. Excellent words as they are, nouns such as concrete and abstract give images which are removed from the technical object. They can be too readily assimilated into the antitechnological bias, to join other words where that bias is cemented into their connotation. Thus they do not escape the perennial distrust embedded in classical humanism where the word machine itself having a meaning similar to machination, is derived from the Greek machine, meaning 'a trick against nature'.

What is needed is not so much a translation as a transduction. To go directly from French to English transposing one word from latin or greek by another having the same origin usually worsens the intended meaning where technology is concerned. Having recognized that literary language is not suitable, the question is what steps must be taken to render mechanology in a mode capable of conveying for a broad audience the significance of the machine for the global culture it is calling forth.

The freshening of language is taking two main routes, the one connected to crafts, the other to Artificial Intelligence. This latter route relates to computer language and computer graphics considered as a form of expression which, like film, renders the essence of the machine accessible insofar as operations are concerned. Like handicrafts, it will help to articulate in a way that the general public will understand, the hidden human elements in the machine. In parallel with that, recent linguistic studies have the important function to bring forward the grasp of the machine from earlier technologies particularly those of the artisan.

For people today to understand, to use and to humanize the machine, it is necessary to start with crafts both old and new. For the crafts show, with a depth of sonance comparable to the sympathy of inter-subjectivity, the image of a lifetime of dialogue between the self and the other. The crafts have had to be kept alive by Morris and others through a kind of Dark Ages, much as writing is said to have been preserved by monks. The crafts did not go unscathed in the process, since they sometimes had to masquerade under inappropriate labels. Resurrected as a defence against the worst features of industrialization, they sometimes assumed a degree of artificiality not in keeping with their older purpose or future possibilities.[1] This was evident in the establishment of hierarchy among different crafts people, acting as a kind of caste system. Even Ghandi calling on the traditions of India, was not able to restore the crafts to their full value in the case of industrialization.

The crafts can act to provide continuity of meaning through direct knowledge of function made specific by the understanding of gesture. Nonverbal knowledge articulated by the hands and feet is the body's way of thinking just as the chiselling of words from sound is the mind's way of

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[1]See the pertinent description of the Arts-and Crafts Movement in J. A. Arguelles, The Transformative Vision, Shambhala, Berkekel, 1975, p. 182.

making contact. Nothing so much prevents the harmonious integration of the human individual as the downgrading of one in favour of the other unless it is loss of hability in both. It is the assertion by Richards of the inconvertable strength and symmetry of the combination which makes her combination of pottery and writing so important.[1] Her concept of centering and fusion as found in the potter's craft has the best chance of providing a language for machine 'concretude' in Simondon. This association belongs to the same process of renewal as the linguistic studies in Britain by Evans where terms used by artisans in the villages has led to the discovery of unexpected treasures in the anglo saxon words associated with the crafts.[2]

The contemporary interest in the body originated, not so much as a reaction against the centuries of rationalism, but as a result of the devastating effects of the shock caused by the advent of automatic machinery. As Marx was acutely aware, it was the replacement of the human hand by the machine tool, which caused the rupture. As long as man perceived himself as demiurge, as master whose hands remodelled nature, his self-image was secure.

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[1] M. C. Richards, Centering in Pottery, Poetry, and the Person Wesleyan University Press, Middletown, 1962.

[2] G. E. Evans, The Days That We Have Seen, Faber and Faber, 1975.

But when the machine or the individual technical object was available not merely as tool but standing in for him in execution as a separate individual, it was equivalent to the loss for man, in a single step, of a crucial part of his inheritance.[1]

That shock has far from been resolved. The entire mythology of the robot, more popular than ever due to the diffusion by film and television, is witness to its continued concern in the minds of the majority of people. But whereas mass media have kept alive and enhanced the irrational fear of technology, the sequence of actual events has not followed the same regressive route. By necessity and through genuine concern, the early patrons of industry recognized that productivity, goal of the factories par excellence, demanded a sound body as much as an efficient machine. Guillerme says that Dupin, one of the originators of French industrial society, was typical of such men in that while he sought to improve the efficiency of the workers, he believed that social harmony could only be realized by the perfectioning of all the faculties of the individual. The importance of athletics, the acquisition of the liberal arts as ornament were the outcome of these attitudes. In the midst of this

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[1]K. Marx, Capital, Volume 1, Vintage Books, 1977, p. 497.

was the need to see the body totally.[1]

The body that was perceived was known very imperfectly and from a standpoint of the very rationalism to which it would be opposed. It was a body image that evolved from "pseudo-mathematized enigma" to "animated motor" to "thermodynamic exchanger".[2] And such models, however valuable they may have been in giving an impetus to physiology and to the modern scientific models of the body, are not to be confused with the soma, the body which industry in its greater concreteness was approaching and which is also itself far from the reality. With respect to the true human body which is asserting itself beneath and beyond these movements, the scientific and technological models are little better than rumours and the considerations of the man/machine relationship only and index or a name.

Along with inadequate knowledge of the technical object, the crisis of value clouds the presence of humanity in the machine and prevents the calling-forth of new creative responses. For some, the achievements of the past provide basis enough for hope. Memories of Chartres

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[1]J. Guillerme, Variations sur les rêveries du Baron Dupin, in Mécanologie 2, p. 54.

[2]Ibid., p. 57.

or Chambord in France, of Stonehenge and the Flying Scotsmen in England, of the geodesic dome and the Boeing 747 in America are sufficient proof of the best in that creative impulse. These individual technical objects do not come about simply through response to necessity but because they are called forth by and supported by creative individuals. They are one of the manifestations of states of revery and places of happiness as ancient as the ringing anvil of the blacksmith and as recent as the smooth spinning of the Stirling engine, states discoverable on the one hand with Bachelard through an archeology of the imagination found in poetry,[1] and on the other with LeMoyne in the "reveries machinques" of the men who work with machines to be found in such places as the "cathedrals of electricity".[2] What is this creative process when it is operative? How is it articulated and what forms does it take? Anticipated in the thesis devoted to the technical object is a later study by Simondon into the nature of invention.[3] In the course of history invention has shown up in three different ways.

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[1]G. Bachelard, La terre et les reveries de la volonté, Jose Corti, Paris, 1948.

[2]J. LeMoyne, Rêveries Machinques, in La Mécanologie, Cahier No. 2, Centre Culturel Canadien, Paris, 1971.

[3]This information comes from G. Simondon, L'invention dans les techniques, in La Mécanologie op. cit., also from course notes, unpublished, Sorbonne, 1968.

In network technology, as exemplified by the mine, improvements come from the centralisation of tasks relative to the pits. Concentration of men and apparatus, flow of materials underground and to the surface, organisation of the ensemble in view of improved operation are the objectives to which the inventive process is directed. This kind of technology is symbolized in the pictures showing the organization of a multitude of people, horses, and pullies to raise an obilisk; it is typical of archaic technology. Creativity comes from resolving the problems connected with the division between the central command and the terminals leading to functional unicity of the terminals. Component technology, the examples being the transformer, the gas piston engine, is characterized by the construction of a tertium quid; invention adds a new third reality linking previously unconnected components. The primary effect of creativity in this order is to produce a device such as the alternating current transformer which links the power of the electric motor to a vast array of equipment such as tools, heaters, radios etc. This is done by envisaging, before manufacture, a unit whose function is to connect two milieux previously separated. Individualized technology is technology focussed on the construction of the complete individual machine of which the house, the automobile the computer are examples. Invention proceeds mainly by evolution of synergies through the process of concretization.

Simondon has observed that the individualized technical object corresponds most directly to the human dimension. The human individual is not dominated by it as he is in the mining or any other network. Nor does he dominate it, making it an extension of his hands or prosthetic device, as happens in component technology. He neither dominates nor is dominated but enters into a kind of dialectic. To understand the categories of this exchange, it is valuable to see the tripartite division of Lafitte as the basis of the mechanology of the individual technical object, these categories depending on whether the machine is primarily devoted to maintaining a homeostatic condition (house, bridge), operating independently (on machine tools, satellites), providing information (computer).

This millenial itinerary of the evolving human species which keeps the process of concretisation before us finds correspondences in the search for the harmonious body functioning which is the goal of physical health. In psychotherapy also, the human soma as perceived in the bioenergetics of Reich and Lowen,[1] is that which concretizes itself, that is, which engages in a search to remember the body into a state of unity corresponding to the magic unity of the child.

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[1]A. Lowen, Bioenergetics, Penguin, Hammondsworth, 1971.

The studies of the crafts and of linguistics as prelude to mechanology take us closer to the centre of somatic reality. They have the effect of joining the distance that has long separated occidental man from the work of his hands. But they too are preparation; means whereby the animated body may begin to be made truly present. The final step is taken through the emanations of the body rooted in the most ancient biological sources. The closest we can come is not through those models which are so useful to science nor through the indices of technology, nor through the elements revealed by close contact with the operations of the crafts and the names of language but only through the original manifestation assumed by the body by way of what Leroi-Gourhan call "le geste et la parole" which is the emanation of the body in ever renewed and creative forms. In this regard the history of the species is one with the moment of upright stature when there took place the simultaneous liberation of the hands from locomotion and the mouth from nourishment. The earliest versions of our humanity such as the Austrolanthrope, "possessed his tools as a kind of pincher. He seemed to have acquired them not in a sort of illumination with which to arm himself but as if his brain and body exuded them progressively."[1] Thus those marvelous

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[1] A. Leroi-Gourhan, Le geste et la parole, Albin Michel, Paris, 1964.

polished stones which mirror for us the conceptions of that oldest humanity are first emanations of the body. If we continue the same process it is due to the fact that the ever-increasing human faculty of symbolization and incarnation bespeak the vitality of the same somatic source.

It is because Simondon has sounded a call to allow the meaning of the machine to resonate at this profound level that his work gains special value in the contemporary reexamination of technology.

Introduction

The purpose of this study is to attempt to stimulate awareness of the significance of technical objects. Culture has become a system of defense designed to safeguard man from technics. This is the result of the assumption that technical objects contain no human reality. We should like to show that culture fails to take into account that in technical reality there is a human reality, and that, if it is fully to play its role, culture must come to terms with technical entities as part of its body of knowledge and values. Recognition of the modes of existence of technical objects must be the result of philosophic consideration; what philosophy has to achieve in this respect is analogous to what the abolition of slavery achieved in affirming the worth of the individual human being.

The opposition established between the cultural and the technical and between man and machine is wrong and has no foundation. What underlies it is mere ignorance or resentment. It uses a mask of facile humanism to blind us to a reality that is full of human striving and rich in natural forces. This reality is the world of technical objects, the mediators between man and nature.

Culture behaves towards the technical object much in the same way as a man caught up in primitive xenophobia behaves towards a stranger. This kind of misoneism directed against machines does not so much represent a hatred of the new as a refusal to come to terms with an unfamiliar reality. Now, however strange this reality may be, it is still human, and a complete culture is one that enables us to discover that this stranger is indeed human. Still, the machine is a stranger to us; it is a stranger in which what is human is locked in, unrecognized, materialized and enslaved, but human nonetheless. The most powerful cause of alienation in the world of today is based on misunderstanding of the machine. The alienation in question is not caused by the machine but by a failure to come to an understanding of the nature and essence of the machine, by the absence of the machine from the world of meanings, and by its omission from the table of values and concepts that are an integral part of culture.

Culture is unbalanced because, while it grants recognition to certain objects, for example to things aesthetic, and gives them their due place in the world of meanings, it banishes other objects, particularly things technical, into the unstructured world of things that have no meaning but do have a use, a utilitarian function. Faced with such a marked defensive negative attitude on the part of a biased culture, men who have knowledge of technical objects and appreciate their significance try to justify their judgment by giving to the technical object the only status that today has any stability apart from that granted to aesthetic objects, the status of something sacred. This, of course, gives rise to an intemperate technicism that is nothing other than idolatry of the machine and, through such idolatry, by way of identification, it leads to a technocratic yearning for unconditional power. The desire for power confirms the machine as a way to supremacy and makes of it the modern philtre (love-potion). The man who wishes to dominate his fellows creates the android machine. He abdicates in favour of it and delegates his humanity to it. He tries to construct the thinking machine and dreams of being able to construct the willing machine or the living machine, so that he can lag behind it, without anxiety, freed from all danger and exempt from all feelings of weakness, while enjoying a vicarious triumph through what he has invented. In this case, then, once through an imaginative process the machine has become a robot, a duplicate of man, but without interiority, it is quite evidently and inevitably nothing other than a purely mythic and imaginary being.

Our precise aim is to show that there is no such thing as a robot; that a robot is no more a machine than a statue is a living being; that is merely a product of the imagination, of man's fictive powers, a product of the art of illusion. Nevertheless, the notion of the machine in present-day culture incorporates, to a considerable extent, this mythic representation of the robot. No cultivated man would allow himself speak of things or persons painted on a canvas as veritable realities with an interior life and a will, good or bad. Despite this, the cultivated man does allow himself to speak of machines which threaten mankind, as if he were attributing to these objects a soul and a separate and autonomous existence which grants them the possession of feelings and of intentions towards mankind.

Our culture thus entertains two contradictory attitudes to technical objects. On the one hand, it treats them as pure and simple assemblies of material that are quite without true meaning and that only provide utility. On the other hand, it assumes that these objects are also robots, and that they harbour intentions hostile to man, or that they represent for man a constant threat of aggression or insurrection. Thinking it best to preserve the first character, culture strives to prevent the manifestation of the second, and speaks of putting the machine in the service of man, in the belief that reducing it to slavery is a sure means of preventing rebellion of any kind.

In fact, this inherent contradiction in our culture arises from an ambiguity in our ideas about automatism--and this is where the hidden logical flaw lies. Idolators of the machine generally assume that the degree of perfection of a machine is directly proportional to the degree of automatism. Going beyond what can be learnt from experience, they suppose that an increase in and improvement of automatism would lead to the bringing into oneness and mutual interconnection of all machines--the creating of a machine made up of all machines.

Now, in fact, automatism is a fairly low degree of technical perfection. In order to make a machine automatic, it is necessary to sacrifice many of its functional possibilities and many of its possible uses. Automatism, and that use of it in the form of industrial organisation which we call automation, has an economic or social, rather than a technical, significance. The real perfecting of machines, which we can say raises the level of technicality, has nothing to do with ~~does not correspond to~~ an increase in automatism but, on the contrary, relates to the fact that the functioning of the machine conceals a certain margin of indetermination. It is such a margin that allows for the machine's sensitivity to outside information. It is this sensitivity to information on the part of machines, much more than any increase in automatism that makes possible a technical ensemble. A purely automatic machine completely closed in on itself in a predetermined operation could only give summary results. The machine with superior technicality is an open machine, and the ensemble of open machines assumes man as permanent organizer and as a living interpreter of the inter-relationships of machines. Far from being the supervisor of a squad of slaves, man is the permanent organizer of a society of technical objects which need him as much as musicians in an orchestra need a conductor. The conductor can direct his musicians only because, like them, and with a similar intensity, he can interpret the piece of music performed; he determines the tempo of their performance, but as he does so his interpretative decisions are affected by the actual performance of the musicians; in fact, it is through him that the members of the orchestra affect each other's interpretation; for each of them he is the real, inspiring form of the group's existence as group; he is the central focus of interpretation of all of them in relation to each other. This is how man functions as permanent inventor and coordinator of the machines around him. He is among the machines that work with him.

The presence of man in regard to machines is a perpetual invention. Human reality resides in machines as human actions fixed and crystalized in functioning structures. These structures need to be maintained in the course of their functioning, and their maximum perfection coincides with their maximum openness, that is, with their greatest possible freedom in functioning. Modern calculating machines are not pure automata; they are technical beings which, over and above their automatic adding ability (or decision-making ability, which depends on the working of elementary switches), possess a very great range of circuit-commutations which make it possible to programme the working of the machine by limiting its margin of indetermination. It is because of this primitive margin of indetermination that the same machine is able to work out cubic roots or to translate from one language to another a simple text composed of a small number of words and turns of phrase.

It is also by the medium of this margin of indetermination, and not by automatisms, that machines can be grouped into coherent ensembles so as to exchange information with each other through the intermediacy of the human interpreter as coordinator. Even when the exchange of information between two machines is direct (such as between a pilot oscillator and another oscillator synchronized by impulses), man intervenes as the being who regulates the margin of indetermination so as to make it adaptable to the greatest possible exchange of information.

Now, we might ask ourselfves who can achieve an understanding of technical reality and introduce it to our culture? It is only with the greatest difficulty that a man attached to a single machine by his work and the routine actions of every day could arrive at such an understanding; an accustomed relationship does not promote this understanding, because doing the same thing over and over blurs, in the stereotypy of acquired gestures, any awareness of structures and function. The fact of managing a business that uses machines, or of owning one, offers no greater likelihood of understanding than does working in one; it creates abstract attitudes towards the machine, causing it to be viewed, not in its own right, but in terms of its costs and the results of its operation. Scientific knowledge, which sees in a technical object the practical application of a theoretical law, is not on the proper level of technical awareness either. ~~is not on the proer level of the technical domain either~~. Rather, it would seem that the attainment of the understanding in question could be the achievement of an organization engineer who is, as it were, a sociologist or psychologist of machines, a person living in the midst of this society of technical beings as its responsible and creative conscience.

In order to restore to culture the really general character which it has lost, it must be possible to reintroduce an understanding of the nature of machines, of their mutual relationships and their relationships with man, and of the values involved in these relationships. This understanding necessitates the existence of the technologist or mechanologist, side by side with the psychologist and the sociologist. Furthermore, the basic systems of causality and regulation which constitute the axioms of technology should be taught universally in the way that the basics of literary culture are taught. An introduction to technics should be put on the same level as scientific education. It is as objective as the use of the arts and it influences practical applications as much as does the theory of physics; it can arrive at the same degree of abstraction and of symbolization. A child should know the meanings of self-regulation or positive reaction as well as he knows mathematical theorems.

This cultural reform carried out by a process of broadening rather than destroying, could give back to present-day culture the real regulating power it has lost. As the basis of meanings, modes of expression, proofs and forms, a culture establishes regulatory communication among those who share that culture. A particular culture arises from the life of the group and, by furnishing norms and systems, informs the actions of those who insure the exercise of authority. Now, before the great development in technics, culture incorporated by virtue of systems, symbols, qualities and analogues, the main kinds of technics that are the source of living experience. Present-day culture does no such thing; it does the contrary. Present-day culture is ancient culture incorporating as dynamic systems artisanal and agricultural techniques of earlier centuries, and doing so in such a way that these systems mediate between groups of people and their leaders and give rise to a basic distortion which results from our inadequacies vis-a-vis things technical. Power becomes literature; it has to do with the manipulation of opinion, with pleading based on appearances, and with rhetoric. The exercise of authority is false because there no longer exists an adequate code of relationships between the reality governed and the beings who govern. The reality governed is made up of man and machines; the code is based on the experience of man working with tools; this very experience is both weakened and remote, because those who use the code have not, like Cincinnatus, just left the handles of the plough. To put is simply, the symbol is weakening and the reality is absent. A regulatory relationship of circular causality cannot be established between the whole of governed reality and the function of authority: information no longer achieves its purpose because the code has become inadequate for the type of information it should transmit. The type of information which expresses the simultaneous and correlative existence of men and machines should involve the systems by which machines function and the values which they imply. Culture, which has become specialized and impoverished, must once again become general. Such an extension of culture is of value both politically and socially because it suppresses one of the main causes of alienation and because it re-establishes regulatory information: it can give man the means of thinking about his existence and his situation in terms of the reality that surrounds him. The task of enlarging and deepening culture has an especially philosophical function, because it leads to a critique of a certain number of myths and stereotypes, such as the idea of the robot and the notion of automata catering to a lazy and fully satisfied humanity.

To bring about the understanding of which we speak, we might attempt to define the technical object in itself by a method of concretization and of functional over-determination, proving that the technical object is the end-product of an evolution and that it is something which cannot be considered as a mere utensil. The modalities of this genesis make it possible to grasp the three levels of the technical object and their temporal, non-dialectic coordination: the element, the individual, and the ensemble.

Once the technical object has been defined in terms of its genesis, it is possible to study the relationship between technical objects and other realities, in particular man as adult and as child.

Finally, considered as the object of an assessment of values, the technical object can give rise to very diverse attitudes, depending on whether it is considered at the level of element, individual, or ensemble. At the element level, its improvement does not lead to any upset that causes anxiety arising out of conflict with acquired habits: it leads to an eighteenth-century climate of optimism, with its introduction of the idea of continued and limitless progress and the constant betterment of man's lot. On the other hand, the machine as technical individual becomes for a time man's adversary or competitor, and the reason for this is that man centralized all technical individuality in himself, at a time when only tools existed. The machine takes the place of man, because man as tool-bearer used to do a machine's job. To this phase corresponds the dramatic and impassioned idea of progress as the rape of nature, the conquest of the world, the exploitation of energies. The will for power is expressed in the technicist and technocratic excessiveness of the thermodynamic era, which has taken a direction both prophetic and cataclysmal. Then, at the level of the technical ensembles of the twentieth century, themodynamic energeticism is replaced by information theory, the normative content of which is eminently regulatory and stabilizing: the development of technics seemed to be a guarantee of stability. The machine, as an element in the technical ensemble, becomes the effective unit which augments the quantity of information, increases negentropy, and opposes the degradation of energy. The machine is a ~~work~~ result of organization and information; it ~~is like~~ resembles life and cooperates with life in its opposition to disorder and to the levelling out of all things that tend to deprive the world of its powers of change. The machine is something which fights against the death of the universe; it slows down, as life does, the degradation of energy, and becomes a stabilizer of the world.

Such a modification of the philosophic view of technical objects heralds the possibility of making the technical being part of culture. This integration, which was not possible in a definitive way either at the level of elements or at the level of individuals, is possible and has a greater chance of stability at the ensembles level. Once technical reality has become regulatory, it can be integrated into culture, which is itself essentially regulatory. Such an integration could only have been possible by addition at the time when technicality resided in elements, or by effraction and revolution at the time when technicality resided in new technical individuals. Today, technicality tends to reside in ensembles. For this reason, it can become a foundation for culture, to which it will bring a unifying and stabilizing power, making culture [redacted]respond to the reality which it expresses and which it governs.

PART ONE

The Genesis and Evolution of Technical Objects

CHAPTER I

"THE GENESIS OF THE TECHNICAL OBJECT: THE PROCESS OF CONCRETIZATION"

I. Abstract Technical Object and Concrete Technical Object

Every technical object undergoes a genesis. It is difficult, however, to define the genesis of each technical object, because the individuality of technical objects is modified in the course of the genesis. What we can do is to define technical objects with reference to the technical species to which they belong, but we can only do so with difficulty. Species are easy to identify summarily for practical purposes, in so far as we are willing to understand the technical object in terms of the practical end it is designed to meet. But such specificity as this is illusory, for no fixed structure corresponds to its defined use. We can get the same result from very different functionings and structures: steam-engines, petrol-engines, turbines, and engines powered by springs or weights are all engines; yet, for all that, there is a more apt analogy between a spring-engine and a bow or cross-bow than between the former and a steam-engine; a clock with weights has an engine analogous to a windlass, while an electric clock is analogous to a house-bell or buzzer. Usage brings together heterogeneous structures and functions in genres and species which get their meaning from the relationships between their particular functions and another function, that of the human being in action. Therefore, anything to which we give a particular name--that of engine, for example--may, perhaps, be multiple even as we speak of it and may vary with time, as it changes its individuality.

Meanwhile, if we wish to define the laws of the genesis of a technical object within the framework of its individuality and specificity, we had better not begin with its individuality or even its specificity but, rather, reverse the problem. If we begin with the criteria of its genesis we can define the individuality or specificity of any technical object. An individual technical object is not such and such a thing, something given <u>hic et nunc</u>, but something that has a genesis.[1] The unity, individuality, and specificity of a technical object are those of its characteristics which are consistent and convergent with its genesis. The genesis of the technical object is part of its being. The technical object as such is not anterior to its own becoming but it is present at every stage of its becoming. The technical object is a unit of becoming. The petrol engine is not any particular, given

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[1]That is, according to the specific modalities that distinguish the genesis of the technical object from those of other kinds of objects, for example an aesthelic object or a living being. These specific modalities should be distinguished from a static modality which could be established following the genesis of the object by taking into account characteristics of various kinds of objects. The precise goal in using the genetic method is to avoid the use of established ideas of classification which come into play once the genesis is complete and which divide the totality of objects into genus and species suitable for discussion. The past evolution of a technical being remains as an essential of this being in its technical form. The technical being, which is a bearer of technicality according to what we call analytic application, cannot be an object of adequate knowledge unless the temporal meaning of its evolution is grasped as something essential to it. The adequate knowledge of which we speak is technical culture, as distinct from technical knowledge, which is limited to the understanding in everyday application of isolated systems of functioning. Since relationships which exist on the level of technicality between one technical object and another are horizontal as well as vertical, the kind of knowledge arrived at by determinations of genus and species is not suitable. We shall try to indicate in what sense the relationship between technical object is transductive.

engine in time and space; it is the fact that there is a sequence, a continuity, which extends from the first engines to those which we know and to those still in evolution. As a consequence, just as in the case of phylogenetic sequences, any particular stage of evolution contains within itself dynamic structures and systems which are at the basis of any evolution of forms. The technical being evolves by convergence and by adaption to itself; it is unified from within according to a principle of internal resonance. The automobile engine of the present day is not a descendant of the 1910 engine simply because the 1910 engine was the one which our ancestors built. Nor is it a descendent of the latter because of greater improvement in relation to use. Indeed, for certain uses the 1910 engine is superior to a 1956 engine. For example, it can withstand a high degree of heating without seizing or leaking, because it is constructed with a considerably greater degree of looseness and without fragile alloys such as white metal; it is also more autonomous, because of its magneto ignition. Old engines still function on fishing boats without breaking down after being taken over from worn-out cars. The present-day car-engine can be defined as posterior to the 1910 engine only through an internal examination of its systems of operation and of its formal construction in the light of those systems of operation. In the modern engine, each critical piece is so connected with the rest by reciprocal exchanges of energy that it cannot be other than it is. The shape of cylinder, the shape and size of the valves and the shape of the piston are all part of the same system in which a multitude of reciprocal exchanges of energy that it cannot be other than it is. The shape of cylinder, the shape and size of the valves and the shape of the piston are all part of the same system in which a multitude of reciprocal causalities exist. To the shape of these elements there corresponds a compression ratio which itself requires a determined degree of spark advance; the shape of the cylinder-head and the metal of which it is made produce, in relation to all the other elements of the cycle, a certain temperature in the spark plug electrodes; this temperature in turn affects the characteristics of the ignition and, as a result, the whole cycle. It could be said that the modern engine is a concrete engine and that the old engine was abstract. In the old engine each element comes into play at a certain moment in the cycle and, then, it is supposed to have no effect on the other elements; the different parts of the engine are like individuals who could be thought of as working each in his turn without their ever knowing each other.

This is very much how the functioning of thermal engines is explained in the classroom; each part is isolated from the rest in geometric space partes extra partes, like the lines of the diagram on the blackboard. The early engine is a logical assembly of elements defined by their total and single function. Each element can best accomplish its particular function if it is like a perfectly finished instrument that is completely oriented towards the accomplishment of that function. A permanent exchange of energy between two elements may be seen as an imperfection if this exchange is not part of their theoretical functioning. Also, there exists a primitive form of the technical object, its abstract form, in which each theoretical and material unity is treated as an absolute that has an intrinsic perfection of its own that needs to be constituted as a closed system in order to function. In this case, the integration of the particular unit into the ensemble involves a series of problems to be resolved, problems that are called technical but which, in fact, are problems concerning the compatibility of already given ensembles.

These already given ensembles ought to be maintained and, in spite of their reciprocal influences, preserved. Then there appear particular structures which, in the case of each of their constituent units, we might call defense structures: the cylinder-head of the thermal internal combustion engine bristles with cooling gills specially developed in the valve region which are subject to intense changes in heat and high pressures. In early engines, the cooling gills are as it were extraneously added on to cylinder and cylinder-head which, in theory, are geometrically cylindrical: they fulfil a single function only, that of cooling. In recent engines, these gills have an added function of a mechanical kind, that of preventing the buckling of the cylinder-head under gaseous thrust. In these conditions, it is impossible to distinguish the volumetric unit (the cylinder or cylinder-head) from the heat-dissipation unit. If one were to grind or saw off the cylinder gills in an air-cooled engine, the volumetric unit constituted by the cylinder alone would no longer be viable, not even as volumetric unit; it would buckle under gaseous pressure. The volumetric and mechanical unit has become co-extensive with the heat-dispersal unit because the structure of the whole is bi-valent. These gills working with currents of air from outside effect changes in temperature and so constitute a cooling surface. In so far as they are part of the cylinder, these same gills limit the size of the combustion chamber by preserving its shape and making it unnecessary to use as much metal as a non-ribbed shell would require. The development of the unique structure is not a compromise but a concomitance and convergence; a ribbed cylinder-head can be thinner than a smooth cylinder-head with the same rigidity. In addition, a thin cylinder-head allows for more efficient thermal changes than would be possible with a thick one. The bi-valent structure of the gill-rib improves cooling not only by increasing the heat-change surface (this is the very function of the gill <u>qua</u> gill) but also by making possible a thinner cylinder-head (and this is the function of the gill as rib).

Therefore the technical problem has to do with the convergence of structures into a structural unity rather than with the seeking of compromises between conflicting requirements. If, in the case in question, a conflict between the two aspects of a single structure is to continue, it can only be possible in so far as the positioning of ribs in the interests of maximum rigidity is not necessarily that which best contributes to maximum cooling by facilitating the flow of air between the gills while the vehicle is running. In that case, the maker can be obliged to settle for a mixed and imperfect design: if the gill-ribs are arranged for the best cooling possible, they should have to be heavier and more rigid than if they were mere gills. If, on the other hand, they are so arranged as perfectly to solve the problem of providing rigidity, they have a larger surface, so as to compensate, by an extension of the surface, for the slowing down of air currents in the heat-change process. Finally, there can even be a structural compromise between the two forms in the very shape of the gills; this would involve a more complex development than would be necessary if a single function were taken as the goal of the structure.

This kind of divergence of functional aims is a residue of abstract design in the technical object, and the progress of a technical object is definable in terms of the progressive reduction of this margin between functions in plurivalent structures. It is such a convergence that gives the technical object its specific identity because, at any given time, an indefinite plurality of functional systems is not possible. Technical species are a great deal more restricted in number than the destined uses of technical objects. Human needs diversify to infinity, but directions of convergence for technical species are finite in number.

The technical object exists, then, as a specific type that is arrived at at the end of a convergent series. This series goes from the abstract mode to the concrete mode: it tends towards a state at which the technical being becomes a system that is entirely coherent with itself and entirely unified.

II. Conditions of Technical Evolution

What are the reasons for the convergence manifest in the evolution of technical structures?--There are beyond doubt a certain number of extrinsic causes, in particular those which lead to the production of standardized units and replacement parts. At the same time, extrinsic causes are no more powerful than those which lead to the multiplication of types in response to an infinite variety of needs. If technical objects evolve in the direction of a small number of specific types it is by virtue of internal necessity and not as a consequence of economic influences or requirements of a practical nature. It is not the production-line which produces standardization; rather it is intrinsic standardization which makes the production line possible. Any attempt to discover the reason for the formation of specific types of technical object in the movement from manual production to industrial production would be based on the fallacy of mistaking the consequence for the condition; the formation of stable types is what makes industrialization possible. Manual trade corresponds to the primitive stage of the evolution of technical objects--that is, to the abstract stage. Industry corresponds to the concrete stage. There is nothing essential about the made-to-measure aspect of the artisan's handicraft. This derives from another, though essential, aspect of the abstract technical object: its being based on an analytical organization which always leaves the way clear for new possibilities, possibilities which are the exterior manifestation of an interior contingency. In the encounter between the coherence of technical work and the coherence of the system of industrial needs, it is the coherence of utilization that prevails. The reason for this is that the made-to-measure object is one which has no intrinsic limits; its norms are imposed from without; it fails to achieve its own internal coherence; it is not a system of the necessary; it corresponds to an open system of requirements.

On the other hand, the object has acquired its coherence on the industrial level, where the system of supply and demand is less coherent than the object's own system. Needs are moulded by the industrial technical object, which thereby acquires the power to shape a civilization. Utilization becomes an ensemble out to the measure of the technical object. When the fancy of some individual demands a made-to-measure automobile, the best thing the maker can do is to take an assembly line engine and an assembly line chassis and modify a few of their external characteristics, adding decorative features and extra accessories as superficial adjuncts to the automobile as the essential technical object. Only non-essential aspects can be made to measure and this is so because they are contingent.

The relationship between non-essential aspects of the technical type and its true nature is negative in kind. The more a car must meet the critical needs of its user the more its essential features are encumbered by an external bondage. The body-work becomes loaded with accessories and the shape no longer approximates a stream-lined structure. The made-to-measure feature is not only non-essential, it works against the essence of the technical being, like a dead weight imposed from without. The car's centre of gravity is raised, and bulk increased.

However, it is not enough to affirm that the evolution of the technical object takes place by a passage from an analytic to a synthetic order which conditions the passage from manual to industrial production. Even if such an evolution is necessary it is not automatic, and it is appropriate that the causes of the evolutionary movement should be investigated. These causes reside essentially in the imperfection of the abstract technical object. Because of its analytic character, this object uses more material and requires more construction work. Though simpler from the logical point of view, technically it is more complicated because it is made from a bringing together of several complete systems. It is more fragile than the concrete technical object, because, in the case of a break-down, the relative isolation of each system constituting a working sub-system threatens the conservation of the other systems. Thus, in an internal combustion engine, the business of cooling could be carried out by an entirely autonomous sub-system. If this sub-system fails to function, the engine can be ruined. If, on the other hand, cooling is a unified effect of the working of the ensemble, the functioning of the engine and the cooling of it are inseparable. In this sense, an air-cooled engine is more concrete than an engine cooled by water. Thermal infra-red radiation and convection are effects that cannot be prevented. They are necessitated by the very working of the engine. Water-cooling is semi-concrete: if it were entirely effected by thermo-syphon* it would be almost as concrete as direct air cooling; but the use of a water-pump which receives its energy from the engine by means of a drive-belt makes this cooling system more abstract in character. Water-cooling can be said to be concrete in so far as it is a security system (the presence of water makes possible an arbitrary cooling for a few minutes because of the absorption of heat energy through vaporization if there is failure in transmission from engine to pump). In normal functioning, however, this is an abstract system. Moreover, an element of abstraction remains in the possibility that there may be no water in the cooling system. Likewise, ignition by current transformer and by battery is more abstract than magneto-ignition, and this is more abstract than ignition by air compression and fuel injection used in Diesel engines. In this sense, it may be said that an engine with magnetic fly-wheel and air cooling is more concrete than the engine in an ordinary car. In it every unit performs a variety of roles. It is not surprising that the scooter should be the result of an airplane engineer's work; whereas the automobile can retain residues of abstraction (e.g. water-cooling, ignition by battery and current transformer) aviation is forced to produce technical objects of the most concrete sort in order to increase functional dependability and to reduce dead weight.

There exists therefore a convergence of purely technical requirements and of economic constraints, such as a decrease in the amount of raw material or of labour or of energy-consumption during use. The object ought not to be self-destructive; it should maintain itself in stable operation for as long as possible. It seems that of the two major causes of technical evolution, the first economic, the other purely technical, it is the second which is of greater importance. Indeed, economic causes are found everywhere. But areas of most active progress are those in which technical conditions outweigh economic conditions (e.g. aviation and war material). Economic causes, then, are not pure; they involve a diffuse network of motivations and preferences which qualify and even reverse them (e.g. the taste for luxury, the desire for novelty which is so evident among consumers, and commercial propaganda). This is so much the case that certain tendencies towards complication come to light in areas where the technical object is known through social myths and opinion-fads and is not appreciated in itself. For example, certain car-manufacturers offer as a great improvement a superabundance of automatisms in accessories or a systematic recourse to power-steering* even when direct steering in no way exceeds the driver's strength; some of them go so far as to use the suppression of direct starting by crank-handle as a sales pitch and as a proof of progress, even though the result is to render functioning more analytical by making it depend on the use of electrical energy in the storage batteries. Although there is a technical complication here, the maker pretends that the suppression in question is a simplification proving the modern character of the car and making obsolete the stereotype idea (an unpleasant one, at that) of the difficult start. This casts nuances of ridicule on other cars--those that have a starting handle--which are therely outmoded and made obsolete by an advertising gimmick. The automobile, this technical object that is so charged with psychic and social implications, is not suitable for technical progress: whatever advances there are in the automobile come from neighbouring areas, such as aviation, shipping, and transport trucks.

The actual evolution of technical objects does not happen in an absolutely continuous manner; it does not happen in an absolutely discontinuous manner either: it involves stages that are definable by the fact that they bring into being successive systems of coherence. There can be an evolution of a continuous kind between the stages that indicate structural reorganization; it results from improvements in detail resulting from what usage reveals and from the production of raw materials, or from better-adapted attachments. Over the past thirty years the automobile has been improving because of the use of metals better adapted to the conditions of its use, because of increased compression-ratios resulting from research into motor-fuels, and because of the study of the precise shape of cylinders and cylinder-heads in terms of the phenomenon of detonation.* The problem of achieving combustion without detonation can only be solved by specific research into the cause of the sound wave inside a petrol mixture at different pressures and temperatures, using different volumes and starting from set points of ignition. But an attempt such as this does not lead to direct uses: the experimental work has still to be done and such trudging towards improvement has its own technicalness. The reforms in structure which allow the technical object to reveal its own specific character are the sheer essentials in the becoming of this object.

Even if there were no scientific advances during a certain period of time, the progress of the technical object towards its own specificity could continue; the principle of progress is none other than the way in which the object causes and conditions itself in its operation and in the feed-back effect of its operation upon utilization. The technical object, the issue of an abstract work of organization of sub-sets, is the theatre of a number of relationships of reciprocal causalty.

These relationships make it possible for the object to discover obstacles within its own operation on the basis of certain limits in the conditions of its use: in the incompatibilities that arise from the progressive saturation of the system of sub-sets there is discoverable an indefiniteness in limitations, and the transcending of these limitations is what constitutes progress.[2] But because of its very nature, such a transcending of limitations can only be arrived at by a leap, by the modification of internal disposition of functions, by a rearrangement of their system; what was an obstacle should become a means of achievement. Take for example the evolution of the electronic tube, of which the radio-tube is the most common kind. Internal obstacles preventing the proper functioning of the triode led to structural improvements which resulted in the current series of tubes. One of the most awkward phenomena in the triode was the critical mutual capacitance within the system formed by the artificial grid and the anode. This capacitance made possible a capacitative coupling between the two electrodes without risk of generating self-oscillation. This unavoidable internal coupling had to be compensated for by external assembl procedures, particularly through a neutralizing effected by the use of an assembly of symmetrical tubes with cross-connected anode-grid coupling.

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[2]These are conditions of individuation of a system.

To resolve the difficulty rather than simply evade it, an electrostatic shroud was introduced into the interior of the triode between the artificial grid and the anode. Now, this adjunction does more than provide the advantage afforded by an electric screen. The screen cannot merely fulfil the decoupling function for which it was intended. When it is placed in the space between grid and anode, its difference in voltage (relative to grid and anode in turn) causes it to act as a grid relative to the anode and as an anode relative to the grid. Its voltage-charge must be made higher than that of the grid and lower than that of the anode; otherwise either there is no transfer of electrons or else electrons move to the screen and not to the anode. Thus the screen plays its part in the transference of electrons from anode to grid. The screen itself is both grid and anode. These two paired functions are not intentionally brought about; they are an extra that happens of its own accord as a result of the character of the system which the technical object presents. For the screen to be introduced into the triode without upsetting its operation, along with tis electrostatic function it has to fulfil certain other functions relating to the electrons in transit. Considered as a simple electrostatic shroud, it could be raised to any voltage whatever, as long as the voltage is continuous, but then it would upset the dynamic functioning of the triode. It necessarily becomes an acceleration grid for the flux of electrons and plays a positive role in the dynamic functioning. It greatly increases internal resistance and, consequently, the coefficient of amplification if it is raised to a specific voltage determined by its exact position in the grid-anode space. So the tetrode is no longer merely a triode lacking electrostatic connection between anode and artificial grid; the tetrode is a steeply curved electronic tube which makes possible a voltage increase in the order of 200, instead of 30 to 50 for the triode.

This discovery, nevertheless, entailed a drawback. In the tetrode, the phonemon of secondary emission of electrons by the anode proved awkward in that it tended to send back to the screen all of the electrons coming from the cathode and bypassing the artificial grid (primary electrons). Because of this, Tellegen introduced a new screen between the first screen and the anode. This is a wide-meshed grid which, when brought to negative voltage in relation to anode and screen (generally the voltage of the cathode or even still more negative), does not hinder accelerated electrons from the cathode from arriving at the anode, but acts as a negatively polarized artificial grid and prevents the return of secondary electrons in the opposite direction. In this way, the penthode is an outcome of the tetrode, in the sense that it comprises a supplementary artificial grid with fixed voltage which completes the dynamic functioning system. Still, the same effect of irreversibility can be obtained by a concentration of electron-flow in beams. If the bars of the accelerating grid-screen are placed in the electric shadow of the artificial grid,there is a great reduction of the phenomenon of seconda emission. Furthermore, the capacity variation between cathode and grid screen in the course of functioning becomes very weak (0.2 ufd instead of 1.8 ufd) which practically suppresses all frequency drift when the tube is used in an oscillator circuit. Consequently, we might say that the tetrode's functioning system is not perfectly complete in itself when we conceive of the screen as a simple electrostatic shrouding, that is, as an enclosed space kept at any constant voltage whatsoever. Such a definition would be too broad and too open, in that it requires a multiple functional incorporation of the screen within the electronic tube--which is brought about by reducing the margin of indetermination of the continuous voltage to be appled to the screen (to make it an accelerator) and by its position in the grid-anode space. A first reduction consists in specifying that the continuous tension should be intermediate between the voltage of the grid and the voltage of the anode. The result is a structure which, in relation to the acceleration of primary electrons, is relatively stable but which, in relation to the trajectory of secondary electrons coming from the anode, is relatively unstable. Such a structure is too open and too abstract. It can be closed in a way that makes it correspond to the needed stable operation either by means of a supplementary structure (e.g. the suppressor or third grid) or by a more precise placing of the grid-screen in relation to the other elements, by aligning its bars with those of the artificial grid. It should be noted that the adjunction of a third grid is equivalent to the adjunction of a higher degree of determination to the placing of the grid screen. The functional character of structures that already exist in reciprocal causality is reversible with the functional character of a supplementary structure. Closing by supplementary determination the causality system in ~~already existant~~ extant structures is equivalent to adding a new structure that is especially designed to perform a determined function. There is a reversibility of function and structure in order to regulate their functioning which renders the object more concrete because this stabilizes its functioning without the addition of a new structure. A tetrode with directed beams is the equivalent of a penthode; it is even superior in its function as amplifier of the power of acoustic frequencies because it produces a lower level of distortion. The adjunction of a supplementary structure is not a real progress for the technical object unless that structure is concretely incorporated into the ensemble of the dynamic systems of its operation. It is because of this that we can say that the tetrode with directed beams is more concrete than the penthode.

We must not confuse an increase in the concrete character of the technical object with any widening of its possibilities resulting from a greater complication of its structure. For example, a twin-grid tube (that allows for the separate action of two mutually independent control grids in a single cathode-anode space) is no more concrete than a triode. It is of the same order as the triode and could be replaced by two independent triodes whose anodes and cathodes would be exteriorly united but whose control-grids would be left independent. On the other hand, the beam-directed tethrode is more fully evolved than the Lee de Forest triode, in that it is a realization of the development or an improvement of the primitive system for modulating the flux of electrons with fixed or variable electric fields.

The primitive triode has a greater degree of indetermination than modern electronic tubes because interactions between structural elements are not defined, with the single exception of the modulatory function of the electric field produced by the control grid. The successive precisions and closures applied to this system transform into stable functions the disadvantages that arise of their own accord in the course of functioning. In the necessity for the negative polarization of the grid in order to counteract heating and secondary emission lies the possibility of dividing the primitive grid into a control grid and an accelerating grid. In a tube containing an acceleration grid, the negative polarization of the control grid can be reduced to a few volts, to one volt in certain cases. The control grid becomes almost entirely a control grid; its function is more effective and the slope of the tube increases. The control grid is brought closer to the cathode while, on the other hand, the secondary grid, or screen, is moved further away and is positioned at approximately an equal distance from the anode and the cathode. At the same time, the functioning becomes more precise; the dynamic system shuts just like an axiomatic system which is saturated. It used to be possible to regulate the slope of the primary triodes by a potentiometric variation of the heater voltage of the cathode acting on the density of the flux of electrons; this possibility hardly available any longer with penthodes that have a steep slope, because an appreciable variation of the heater voltage would profoundly alter their characteristics.

It seems contradictory, surely, to affirm that the evolution of a technical object depends upon a process of differentiation (take for example, the command grid in the triode dividing into three grids in the penthode) and, at the same time, a process of concretization, with each structural element filling several functions instead of one. But in fact these two processes are tied one to the other. Differentiation is possible because this very differentiation makes it possible to integrate into the working of the whole--and this in a manner conscious and calculated with a view to the necessary result--correlative effects of overall functioning which were only partially corrected by palliative measures unconnected with the performance of the principal function.

A similar kind of evolution is noticeable in the change between the Crookes tube and the Coolidge tube. The former is not only less effective that the latter; it is also less stable in its functioning and more complex. The Crookes tube uses cathode-anode voltage to separate molecules or atoms of monoatomic gas into positive ions and electrons and then to accelerate the electrons and to give them a critical kinetic energy before collision with the anticathode. In the Coolidge tube, on the other hand, the function of producing electrons is dissociated from that of accelerating electrons already produced; the production is caused by a thermoelectric effect (which is improperly called thermoionic, no doubt because it replaces the production of electrons by ionization) and the acceleration takes place later; thus, the functions are purified by their dissociation and the corresponding structures are at the same time more distinct and more productive. The hot cathode of the Coolidge tube is more productive from the point of view of structure and function than the cold cathode of the Crookes tube. Still, looked at from the electrostatic point of view, it is equally perfect as a cathode, and all the more so because it comprises a rather narrowly localized area for generating thermoelectrons and because the surface shape of the cathode surrounding the filament insures an electrostatic gradient which allows for a focusing of electrons in a thin beam falling on the anode (a few square millimeters in area in the tubes of today). In the Crookes tube, on the other hand, the area for the generating of electrons is not sufficiently narrowly defined to make possible a really effective focusing of the beam to obtain a source of X-rays that approaches an ideal point of convergence.

Besides, the presence of ionizable gas in the Crookes tube involved more than the problem of instability (the hardening of the tube by the impingement of molecules on the electrode, as well as the need for arranging valves through which gas may be re-introduced into the tube). The presence of gas also involved an essential disadvantage, in that gas molecules presented an obstacle to already produced electrons in the course of their acceleration in the electric field between cathode and anode. This disadvantage is a typical example of the kinds of antagonism that comes into play in the evolution of abstract technical object: the very gas which is necessary for the production of electrons to be accelerated is an obstacle to their acceleration. This antagonism disappears in the Coolidge tube, which has a high vacuum. It disappears because the groups of synergetic functions are distributed in defined structures, each structure gaining by this redistribution a greater functional productivity and an improved structural precision. This is so in the case of the cathode, which instead of being a simple spherical or hemispherical case made of any particular metal becomes an ensemble made of a parabolic bulb at the centre of which there is a filament producing thermoelectrons. The anode, which in the Crookes tube occupied any position in regard to the Cathode, becomes geometrically identified with the earlier anticathode. The new anode-anticathode plays two synergetic roles; in the first case, it produces a difference in potential relative to the cathode (this is its anode role); in the second, it constitutes an obstacle against which accelerated electrons collide as a result of a drop in potential, transforming their kinetic energy to light energy of very short wave-length.

These two functions are synergetic because it is only after they have undergone the entire drop in potential in the electric field that the electrons have acquired maximum kinetic energy. Therefore, only at this moment and place is it possible to draw from them the greatest possible amount of electromagnetic energy by suddenly stopping them. The new anode-anticathode then plays a role in the evacuation of the heat produced (due to the inefficiency of the transformation of kinetic energy of electrons to electromagnetic energy, about 1%), and this new function is fulfilled in perfect agreement with the two preceding functions. A plate of hard-to-melt metal such as tungsten is embedded in the large bevelled copper bar which forms the anode-anticathode at the point of impact of the beam of electrons. The heat developed on this plate is conducted to the outside of the tube by the copper bar which is extended in cooling flanges on the outside.

The three functions are synergetic because the electric properties of the copper bar, which is a good conductor of electricity, are on a par with the thermic properties of the same bar, which is a good conductor of heat. Besides, the bevelled section of the copper bar is equally suited to its functions as target-obstacle (anode), as accelerator of electrons (anode) and as evacuator of the heat produced. In these conditions one could say that the Coolidge tube is a Crookes tube that is both simplified and concretized and in which each structure fulfills many functions which are synergetic in nature. The imperfection of the Crookes tube with its abstract and artisanal character, which make necessary frequent adjustments as it functions, arose from the antagonism of functions filled by the rarefied gas--the gas which is suppressed in the Coolidge tube. Its indistinct structure corresponding to ionization is wholly replaced by the new thermoelectronic characteristic of the cathode, which is perfectly distinct.

Thus, these two examples tend to show that differentiation proceeds in the same direction as the condensation of multiple functions in the same structure, because the differentiation of structures at the core of a system of reciprocal causalties allows for the suppression (by integration into the functioning) of secondary effects that were formerly obstacles. The specialization of each structure is a specialization of positive, functional, synthetic unity which is free of unlooked-for secondary effects that amortize this functioning. The technical object improves through the interior redistribution of functions into compatible unities, eliminating risk or the antagonism of primitive division. Specialization is not achieved _function by function_ but _synergy by synergy_. What constitutes the real system in a technical object is not the individual function but the synergetic group of functions. It is because of the search for synergies that the concretization of the technical object can be seen as an aspect of simplification. The concrete technical object is one which is no longer divided against itself, one in which no secondary effect either compromises the functioning of the whole or is omitted from that functioning. In this way and for this reason, in a technical object which has become comcrete, a function can be fulfilled by a number of structures that are associated synergetically, whereas in the primitive and abstract technical object each structure is designed to fulfil a specific function and generally a single one. The essence of the concretization of a technical object is the organizing of functional sub-systems into the total functioning. Starting from this principle, we can understand precisely how the redistribution of functions is brought about in a network of different structures, in abstract as much as in concrete objects. Each structure fulfils a number of functions; but in the abstract technical object each structure fulfils only one essential and positive function that is integrated into the functioning of the whole, whereas in the concrete technical object all functions fulfilled by a particular structure are positive, essential, and integrated into the functioning of the whole. Those marginal consequences of functioning which in the abstract technical object are eliminated or attentuated by correctives, become evolutionary stages or positive aspects of the concrete object. The functioning scheme incorporates marginal aspects, and effects which were of no value or were prejudicial become links in the chain of functioning.

This progress assumes that each structure is consciously endowed by its maker with characteristics which correspond to all the components of its functioning, as if an artificial object differed in no way from a physical system studied in all knowable aspects of energy exchange and of physical and chemical transformations. In the concrete object each piece is not merely a thing designed by its maker to perform a determined function; rather, it is part of a system in which a multitude of forces are exercised and in which effects are produced that are independent of the design plan. The concrete technical object is a physicochemical system in which mutual actions take place according to all the laws of science. The ultimate goal of the design can only be perfectly realized in the construction of the object if it identified with universal scientific knowledge. One must insist that the knowledge in question must be universal, because the fact that the technical object belongs to the class of artifacts which meet a certain specific human need in no way limits or defines the type of physicochemical actions which can occur in this object or between this object and the outside world. Whatever difference exists between a technical object and a physicochemical system studied as an object exists only in the imperfection of science. The kinds of scientific knowledge that serve as a guide to predict the universality of mutual actions taking place in a technical system are by no means free of imperfection. They do not make possible an absolute and rigorously precise forecast of all effects. This is why there is a certain gap between the system of technical intentions related to a particular goal and the scientific system of the knowledge of causal interactions that achieve this goal. The scientific object is never completely known. For this very reason, it is never completely concrete either, except in the rarest of chance occurrences. The ultimate assignment of functions to structures and the exact calculation of structures could only be accomplished if scientific knowledge of all phenomena that could possibly occur in the technical object were fully acquired. Since this is not the case, there continues to exist a clear difference between the technical system of the object (comprising the representation of a human goal) and the scientific picture of the phenomena to which it gives rise (comprising only systems of efficient causalty, whether mutual or recurrent).

Concretization of technical objects is conditioned by the narrowing of the gap separating science from technics. The primitive artisanal phase is characterized by a weak correlation between the scientific and the technical, while the industrial phase is characterized by improved correlation. Industrial construction of a specific technical object is possible as soon as the object in question becomes concrete, which means that it is understood in an almost identical way from the point of view of design plan and scientific outlook. This explains why certain objects have been capable of being constructed industrially long before others. The windlass, the hoist, tackle-blocks and the hydrolic press are all technical objects in which such phenomena as friction, electrization, electrodynamic induction, and thermal and chemical exchanges can, in the majority of cases, be ignored without any possibility of the object's being destroyed or if its functioning improperly. Classical rational mechanics makes possible a scientific understanding of the functioning of those objects which we call simple machines; nevertheless, in the seventeenth century the industrial construction of a gas-run centrifuge pump or a thermal engine would have been impossible. The first thermal engine to be constructed industrially, Newcommer's, used depression only, and the reason for this was that the phenomenon of vapour condensation under cooling influences was scientifically known. Likewise, electrostatic machines have remained artisanal almost to our own day, because, although the phenomena of dielectrical projection and transport of charges and the flow of these charges by Corona effect have been qualitatively known since the eighteenth century at least, they have never been the object of very rigorous scientific study. After the Wimshurst machine, the Van de Graaf generator itself retains something of the artisanal, for all its great size and increased power.

III. The Rhythm of Technical Progress; Continuous and Minor Improvement and Discontinuous and Major Improvement

The discovery of functional synergies is the essential characteristic of progress in the development of the technical object. So it is appropriate that we should ask ourselves whether this discovery is made all at once or in a continuous manner. Insofar as the reorganization of structures affects functioning, it comes about abruptly, though it may involve many successive steps; so the Coolidge tube could not have been conceived before Fleming's discovery of the production of electrons by a heated metal. But the Coolidge tube with its static anode-anticathode is not necessarily the final version of the tube which produces X-rays or Gamma rays. It is open to improvement and can be appropriated to more particular uses. For example, an important improvement that allows for the discovery of a source of X-rays closer to the ideal geometric point has been arrived at by the use of an anode in the form of a large plate mounted on an axis within the tube. This plate can be set in motion by a magnetic field created by a conductor placed outside the tube and in relation to which the plate acts as a rotor comprising an induced circuit. The region of electron impact becomes a circular line close to the edge of the copper plate and, because of this, it presents very great possibilities of thermal dissipation. Nevertheless, statistically and geometrically, the place of impact is fixed in relation to cathode and tube. The X-ray beam therefore derives from a geometrically fixed centre, although the anticathode goes by this fixed point at great speed. Tubes with a rotating anode allow for an increase in power without an increase in the size of the area of impact, and for a reduction in power. So, the rotating anode fulfils the functions of speeding and stopping electrons as efficiently as does a fixed anode. It is more efficient in the business of heat-evacuation, and this permits an improvement of the optical properties of the tube for a given power.

Ought we, for this reason, to consider that the invention of the rotating anode brings a structural conretization to the Coolidge tube? No, because its special role is to lessen a disadvantage which could not be converted into a positive aspect of the functioning of the whole. The disadvantage of the Coolidge tube, the residual antagonism continuing in its functioning, is its low efficiency in converting kinetic energy to electromagnetic radiation. Without doubt, this low efficiency does not constitute a direct antagonism between functions, but in practice it effects a real antagonism. If the melting temperatures of the tungsten plate and of the copper bar were to be raised infinitely, it would be possible to bring to a very precise focus a very powerful beam of very rapid electrons. But, since in fact the melting point of tungsten is fairly quickly reached, we find that this low efficiency is a limitation which produces a great amount of heat, so we must decide to sacrifice the sharpness of the beam, or the density of electron-flow, or the speed of electrons; this means that we must sacrifice the punctuality of the X-ray source, the amount of electromagnetic energy radiated, or the penetration of the resulting X-rays. If only we could discover a means of increasing the efficiency of energy transformation which occurs on the anticathode plate, every characteristic of the Coolidge tube would be improved by the elimination or diminution of the most critical antagonisms in its functioning. (A much weaker antagonism consists in the impossibility of sharply focusing the beam because of the mutual repulsion of electrons which are affected by electrical charges of the same sign; it could be compensated for by means of devices for beam-focussing comparable to those of cathode type oscilloscopes, of electrostatic lenses, or of the electromagnetics of electronic microscopes.) The rotating anode makes possible the reduction of the consequences of the antagonism between sharpness and power, and between optical and electonic characteristics.

There are two kinds of improvements, then: those which modify the division of functions, increasing in an essential manner the synergy of functioning, and those which without modifying the division in question diminish the harmful effects of residual oppositions. To this order of minor improvement belong: a more regular system of lubrication in an engine, the use of self-lubricating bearings, and the use of metals of higher resistance or of more solid assembly. So, in electronic tubes, the discovery of the increased transmitting power of certain oxides or of metals such as thorium has made possible the construction of oxide cathodes that operate at a lower temperature and absorb less heat energy for the same density of electron flow. Though this improvement is of practical importance it remains minor, and it is only suitable for certain kinds of electronic tubes because of the relative fragility of the oxide covering. The rotating anode of the high-power Coolidge tube is a minor improvement such as the discovery of a more highly efficient energy transformation that would made it possible to reduce to a few hundred watts the power needed to accelerate the electrons, where present-day X-ray tubes need many kilowatts.

In this sense, it could be said that minor improvements adversely affect major improvements because they blind us to the real imperfection of a technical object that makes use of non-essential devices, which are not completely integrate into the functioning of the whole, to compensate for real antagonisms. The characteristic problems of abstraction become evident anew in the case of minor improvements. Thus, the Coolidge tube with its rotating anode is less concrete than a tube with static cooling provided by copper bars and flanges in the air. If, for whatever reason, the anode rotation stops while the tube is functioning, the point of the anode receiving the concentrated beam of electrons begins to melt almost instantly and the whole tube is ruined. Such an analytic property of the functioning therefore makes necessary another species of correctives--security systems obtained by the conditioning of one operation by means of another operation. In the case just analysed, it is necessary that the generator of anode voltage should function only if the anode is already turning. A relay controls the application of voltage to the transformer, which supplies the anode voltage for the passage of current into the circuit of the anode motor. But this subordination does not entirely reduce the analytic distance introduced by the rotating anode device; the current can pass into the anode without an effective turning of the anode, as a result of the deterioration of axles for example. Likewise, the relay can remain switched on even when the inductor is not subject to voltage.

An extreme complication and improvement of appended systems of security or compensation can only tend towards the equivalent of the concrete in a technical object, though it neither attains nor prepares for this, simply because the way of concretization has not been chosen. The course of minor improvements is one of detours; useful as they are in certain cases of practical use, they hardly lead to the evolution of the technical object. Minor improvements conceal the true and essential system of each technical object beneath a pile of complex palliatives; they encourage a false awareness of the continuity of progress in technical objects while, at the same time, diminishing the value of essention transformations and lessening our sense of urgency about them. For this reason, continuous minor improvements provide no clear boundary in relation to the false renovations which commerce requires in order to pretend that a recent object is an improvement on the less recent. Minor improvements can be so non-essential as to be hidden by the cyclic rhythm of shapes which fashion super-imposes on the essential lines of utilitarian objects.

It is not enough to say, therefore, that the technical object is one which has a specific genesis proceeding from the abstract to the concrete. Once again, it must be specified that this genesis is achieved by essential and discontinuous improvements that bring about modifications in the internal system of the technical object, and do so in leaps and not along a continuous line. This does not mean that the development of the technical object is brought about by chance or that it is independent of any assignable meaning. On the contrary, it is minor improvements which to a certain extent come about by chance and obscure by their incoordinated proliferation the pure lines of the essential technical object. The real stages of improvement of the technical object are achieved by mutations, but by mutations that have meaningful direction; the Crookes tube potentially contains the Coolidge tube, because the very intention which becomes organized, stabilized, and refined in the Coolidge tube already existed in the Crookes tube in a confused but nevertheless real state. Many abandoned technical objects are incomplete inventions which remain as an open-ended virtuality and could be taken up once more and given new life in another field according to the profound intention which informs them, that is, their technical essence.

IV. Absolute Origins of a Technical Lineage

Like every evolution, the evolution of technical objects raises the problem of absolute origins. To what first beginning can we return in order to establish the coming into existence of a specific technical reality? Before the penthode and the tethrode there was the Lee de Forest triode. Before the Lee de Forest triode there was the diode. But what was there before the diode? Is the diode an absolute origin? Not completely. There is no doubt that thermoelec tric emission was then unknown, but the phenomena of transport of charges in space by an electric field had long been known; electrolysis had been known for a century, and the ionization of gas for many decades. Thermoionic emission is necessary for the diode as a technical system, because the diode would not be a diode if the transport of electric charges were reversible. Such reversibility does not occur under normal conditions, because one of the electrodes is hot and, consequently, emissive, and the other cold, and, consequently, non-emissive. What makes the diode essentially a diode, a two-way valve, is the fact that the hot electrode can be almost interchangeably either cathode or anode, while the cold electrode can only be an anode, as it cannot emit electrons; it can only attract them if it is positive, but it cannot emit them even if, in relation to another electrode, it is negative. The result of this is that if external voltages are applied to the electrodes, current will pass through because of the thermoelectronic effect if the cathode is negative in relationg to the anode, but no current will pass through if the hot electrode is positive in relation to the cold electrode. What constitutes the diode is precisely this discovery of a condition of functional dissymmetry and not, properly speaking, the transport of electric charges across a vacuum by means of an electric field. Experiments having to do with the ionization of monoatomic gases had earlier demonstrated that free electrons can move about in an electric field. But this is a reversible, not a polarized, phenomenon; if the rarified gas tube is turned around, the positive pole and the luminous rings change sides in relation to the tube, but their position remains unchanged in relation to the direction of current from generator. The diode is made fromthe association of this reversible phenomenon of the transport of electric charges through a field and from the condition of reversibility effected by the fact that transportable electric currents are produced by one single kind of electric charge (negative only) and by only one of the two electrodes, is one hot and one cold electrode, between which an electric field is created. Here we surely have an <u>absolute beginning</u>; it is to be found in the condition of irreversibility of the electrodoes and the phenomenon of the transport of electric charges across the vacuum; here we have the creation of a <u>technical essence</u>. The diode is an asymmetric conductance.

It is to be noted, however, that this essence is more extensive than the definition of the Fleming valve. Many other procedures have been discovered for creating asymmetric conductance. The contact of galena with a metal, of copper oxide with copper, of selenium with another metal, of germanium with a tungsten point, as well as of crystalized silicon with a metal point are all asymmetrical conductances. Finally, a photoelectric cell could be considered as a diode, because the photo-electrons behave like thermoelectrons in the vacuum of the cell (in vacuum cell and also in gas cell, though the phenomenon is complicated by the emission of secondary electrons which become attached to the photoelectrons). Should the Fleming valve be called a diode therefore? Technically, the Fleming valve can be replaced in a number of applications by germanium diodes (for weak intensities or high frequencies) or by selenium or copper oxide rectifiers (for applications with low frequency and high intensity). But usage does not supply good criteria. The Fleming valve can also be replaced by a rotating transformer,* a technical object whose essential system is entirely different from that of the diode. In fact, the thermoelectronic diode constitutes a definite type with its own historical existence. Above this type there exists a pure functioning system which is transposable into other structures, for example into those of imperfect conductors or semi-conductors. The functioning system is the same, to the extent that on a theoretic diagram a diode can be indicated by a sign (asymmetric conductance: ⊁) which does not prejudge the

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*See Appendix

type of diode used and which leaves complete freedom to the builder. But the pure technical diagram does define a type of existence for the technical object in terms of its ideal function, which differs from the reality of the historic type. Historically, the Fleming diode is nearer to the Lee de Forest triode than to germanium, copper oxide or selenium and iron rectifiers, though these are indicated by the same schematic symbols and, in certain cases, fulfil the same functions, even to the point of being replaceable by the Fleming diode. The whole essence of the Fleming tube is not contained in its property of asymmetric conductance; it is also a device that produces and transports the flow of electrons that are capable of being slowed down, accelerated and deviated, and that can be dispersed or concentrated, repulsed or attracted. The technical object exists not only by virtue of its functioning in exterior devices (for example, an asymmetric conductance) but by virtue of phenomena of which it is, itself, the centre. This is why is posesses a fecundity or non-saturation which grants it a progeny.

The primitive technical object can be considered as a non-saturated system. Whatever later improvements it undergoes act as steps forward towards the saturation of the system. Judging from the outside, it is possible to believe that, instead of being improved, the technical object is becoming altered and is changing its structure. But it could be said that the technical object evolves by engendering a family; the primitive object is the forefather of this family. We could even call such an evolution a natural technical evolution. In this sense, the gas engine is the forefather of petrol and diesel engines, the Crookes tube forefather of the Coolidge tube, and the diode forefather of the triode as well as of other multiple-electrode tubes.

At the start of each such series there is a definite act of invention. In a certain sense the gas engine derives from the steam engine; the placing of its cylinder, piston, transmission system, as well as its distribution by slide-valve and slots, is analogous to the steam engine's. What was needed was a new phenomenon, a system which existed neither in the steam engine nor the discharge tube. In the steam-engine, both the boiler, producing gas under pressure, and the heat source were outside of the cylinder. In the gas engine, the cylinder itself, as explosion chamber, becomes both boiler and furnace; combustion takes place within the cylinder: combustion is internal. In the discharge tube, the electrodes were indistinguishable and conductance remained symmetrical; the discovery of thermo-electronic effect allows for the making of a tube analogous to the discharge tube in which electrodes are polarized, thus rendering the conductance symmetrical. The beginning of a lineage of technical objects is marked by a synthetic act of invention that is basic to a technical essence.

Technical essence is recognizable by the fact that it remains stable all through the course of evolution and that, further, it not only remains stable but is ever capable of producing structures and functions by internal development and progressive saturation. That is why the technical essence of the combustion engine could become that of the diesel engine by increased concretization of function. In an engine with preliminary combustion, the heating of the fuel mixture within the cylinder at the moment of compression is inessential and even harmful, because of the risk of producing detonation instead of deflagration (combustion with progressive explosive wave) which limits the admissable compression ratio for a given kind of motor fuel. In the diesel engine on the other hand, compression heat becomes an essential and positive factor, because it initiates deflagration. What gives compression a positive role is a more precise fixing of the exact time of carburation. In an engine with preliminary combustion, carburation can take place at any time before the introduction of the fuel mixture into the cylinder. In a diesel engine carburation must take place after the introduction and compression of pure air, which is free of carburating fumes, at the precise moment when the piston reaches the top dead point, because this introduction initiates deflagration (the start of the cycle's power-time) and cannot initiate it unless it occurs at the instant when the air reaches its highest temperature at the end of compression. The introduction of motor fuel into the air (carburation) is, for this reason, charged with much more functional significance in the diesel engine than in the gasoline engine. It is integrated into a more saturated and rigorous system, which allows the builder less freedom and the user less tolerance.

The triode is also a more saturated system than the diode. In the diode the only factor that limits asymmetric conductance is thermoelectronic emission. When the cathode-anode voltage is raised, the internal current progressively increases for a temperature established by the cathode, but reaches a certain ceiling (saturation current) which corresponds to the fact that all electrons emitted by the cathode are collected by the anode. Therefore the only way to regulate the current crossing the diode is to vary the anode voltage. On the other hand, the triode is a system in which the current crossing the anode-cathode space can be made to vary on a continuous basis without any varying of cathode-anode voltage. The primitive property remains (that is, the variation of current as a direct function of cathode-anode voltage) but it is paired with a second possibility of variation which fixes the voltage of the control grid. The function of variation which in the primitive state was tied to anode voltage now becomes individualized, free and definite; this adds an element to the system and, as a result, saturates it because the system of causality includes an extra component.

In the evolution of the technical object the saturation of the system by segregation of functions becomes accentuated. In the penthode, the current crossing the cathode-anode space becomes independent of anode voltage for values of anode voltage between a low minimum and high maximum related to the possibility of thermal dissipation. This characteristic is stable enough to make possible the use of the penthode as a charge resistance in relaxation oscillators that are needed for the production of linear saw-teeth for the horizontal sweep voltages of cathode-ray oscillographs. In this particular case, the voltages of screen, control-grid, and third grid (suppressor) are kept constant. This is not the case with the triode, where for a given control-grid voltage anode current varies as a function of anode voltage. In this sense, the triode is still assimilable to a diode, whereas this is no longer true of the penthode, in the dynamic system. The basis for this difference is the fact that in the triode the anode continues to play an ambivalent role: a dynamic role as electrode collecting electrons and a static role as electrode creating an electric field. In the tetrode or penthode, on the other hand, it is the grid-screen, playing its electrostatic anode role, that assures the maintenance of the electric field, by regulating the electron flow. The anode-plate has a single role to play, that of electron collector. For this reason the slope of the penthode can be much greater than that of the triode, because the function of maintaining the electrostatic field of acceleration is guaranteed without variation or diminution (the screen is at a fixed potential), even when anode voltage dips when there is an increase in current, because of the insertion of a charge resistance in the anode circuit. We can say that the tetrode and penthode eliminate the antagonism that exists in the triode, an antagonism between its function as accelerator of electrons by the anode and its function as collector of electric charges conveyed by the electrons that are accelerated by the same anode; this function occasions a drop in anode potential when a charge resistance is inserted, and it lessens electron acceleration. From this point of view, the grid-screen should be considered as an electrostatic anode of fixed voltage.

It is obvious, therefore, that the tetrode and the penthode are indeed results of a development of the primitive diode system through saturation and synergetic concretization. The grid-screen concentrates in itself all the functions relative to the electrostatic field that have to do with the maintenance of a fixed potential. The control-grid and the anode maintain no other functions than those that have to do with a variable potential, and they can perform these functions to a much greater extent (in the course of operation, the anode of a penthode used as a voltage amplifier can be raised to potentials varying between 30 and 300 volts in the dynamic system). The control grid collects fewer electrons than it would in a triode and this makes possible to treat the input impedance as very high. The control grid becomes much more purely a control grid, and it is no longer subject to continuous current created by the collecting of electrons. It is, in a much more rigorous sense, an electrostatic structure. Thus, the tetrode and penthode can be considered to be direct descendants of the triode: the development of the triode's internal technical system is realized in them through a reduction of incompatibilities by means of a redistribution of functions in synergetic subsystems. What establishes the unity and distinctiveness of a technical lineage is the stability of an underlying system of invention that is at once concrete and controlling.

Concretization gives the technical object an intermediate position between natural object and scientific representation. The abstract, or primitive, technical object is far from constituting a natural system. It is a translation into matter of an ensemble of scientific notions and principles that at the most basic level are unconnected one with the other and that are connected only by those their consequences that converge for the production of a looked-for result. The primitive technical object is not a physical natural system but a physical translation of an intellectual system. It is an application, therefore, or a bunch of applications. It is a consequence of knowledge and it can teach nothing. It is not subject to inductive examination, as a natural object is, and the reason for this is that it is nothing if not artificial.

The concrete technical object, that is, the evolved technical object, is quite the opposite in that it approximates the mode of existence of natural objects. It tends to internal coherence, and towards a closure of the system of causes and effects which operate in circular fashion within its boundaries. Further, it incorporates part of the natural world which intervenes as a condition of its functioning and, thus, becomes part of the system of causes and effects. As it evolves such an object loses its artificial character: the essential artificiality of an object resides in the fact that man has to intervene in order to keep the object in existence by protecting it from the natural world and by giving it a status as well as existence.

Artificiality is not a characteristic that denotes the manufactured origin of the object as opposed to nature's productive spontaneity.

Artificiality is something that is within the artificializing action of man, regardless of whether this action affects a natural object or an entirely fabricated object. A greenhouse developed blossom that yields petals (a double flower) but does not engender fruit is the product of a plant that has been made artificial. Man has deflected the plant's functions from coherent performance to the extent that the plant can't reproduce itself except by procedures such as grafting which require human intervention. Making a natural object artificial gives results that differ from those effected by technical concretization. A plant that has been made artificial can only exist in that plant laboratory, the greenhouse, with its complex system of thermic and hydraulic regulations. The initially coherent system of biological functions has been opened up to functions that are independent of each other and that are related to one another only by the gardener's care. Flowering becomes pure flowering, something detached and anomic; the plant blooms until it is worn out and it produces no seeds. It loses its original abilities to resist cold, drought and solar heat. The artificial regulations of the greenhouse replace what originally were the object's natural regulations. Artificialization is a process of abstraction in the object which is rendered artificial.

By technical concretization, on the other hand, an object that was artificial in its primitive state comes more and more to resemble a natural object. In its beginning, the object had need of a more effective exterior regulatory environment, for example a laboratory or a workshop or, in certain cases, a factory. Little by little, as it develops in concretization, it becomes capable of doing without the artificial environment, and this is so because its internal coherence increases and its functioning system becomes closed by becoming organized. A concretized object is comparable to an object that is produced spontaneously. It becomes independent of the laboratory with which it is initially associated and incorporates it into itself dynamically in the performance of its functions. Its relationship with other objects, whether technical or natural, becomes the influence which regulates it and which makes it possible for the conditions of functioning to be self-sustaining. The object is, then, no longer isolated; either it becomes associated with other objects or is self-sufficient, whereas at the beginning it was isolated and heteronomous.

The consequences of the concretization under discussion are not merely human and economic (by warranting decentralization, for example), they are also intellectual. Because the mode of existence of the concrete technical object is analogous to that of a spontaneously produced natural object, we can legitimately consider them as natural objects; this means that we can submit them to inductive study. They are no longer merely applications of certain anterior scientific principles. In that they exist, they prove the viability and the stability of a certain structure which has the same status as a natural structure, though it can be schematically different from all natural structures.

The study of the systems of functioning in concrete technical objects is valuable scientifically because these objects are not derived from a single principle. They are the evidence of a certain mode of functioning and of compatibility that exists in fact and that was constructed before being foreseen. The compatibility in question was not contained in each of the distant scientific principles which played their part in the construction of the object; it was empirically discovered. In order to verify this compatibility, we can go back to the separate sciences in order to pose the problem of the correlation of their principles; to do so would be found a science of correlations and transformations, which would be a general technology or mechanology.

But in order to give direction to the general technology just referred to it is necessary to avoid basing it on an improper assimilation of technical object to natural object, particularly to the living. Analogues or, rather, exterior resemblances should be rigorously outlawed, because they lack signification and can only lead astray. Cogitation about automata is unsafe because of the risk of its being confined to a stury of exterior characteristics and so work in terms of improper comparison. What alone is significant is exchanges of energy and information within the technical object or between the technical object and its environment; outward aspects of behaviour observed by a spectator are not objects of scientific study.

It would not even be right to found a separate science for the stury of regulatory and control mechanisms in automata built to be automata: technology ought to take as its subject the universality of technical objects. In this respect, the science of Cybernetics is found wanting; even though it has the boundless merit of being the first inductive stufy of technical objects and of being a study of the middle ground between the specialized sciences, it has particularized its field of investigation to too great an extent, for it is part of the study of a certain number of technical objects. Cybernetics at its starting point accepted a classification of technical objects that operates in terms of criteria of genus and species: the science of technology must not do so. There is no species of automata: there are simply technical objects; these possess a functional organisation, and in them different degrees of automatism are realized.

There is one element that threatens to make the work of Cybernetics to some degree useless as an interscientific study (though this is what Norbert Weiner defines as the goal of his research), the basic postulate that living beings and self-regulated technical objects are identical. The most that can be said about technical objects is that they tend towards concretization, whereas natural objects, as living beings, are concrete right from the beginning. There should be no confusing of a tendency towards concretization with a status of absolutely concrete existence. Though every technical object possesses to some degree aspects of residual abstraction, one cannot go to the extent of speaking of technical objects as if they were natural objects. Technical objects must be studied in their evolution in order that the process of concretization as tendency can be abstracted therefrom. Still, the final product of the technical evolution does not have to be isolated so that it can be defined as entirely concrete; it is more concrete than what preceded it, but it is still artificial. Instead of considering one class of technical beings, automata, we should follow the lines of concretization throughout the temporal evolution of technical objects. This is the only approach that gives real signification, all mythology apart, to the bringing together of living being and technical object. Without the goal thought out and brought to realization by the living, physical causality alone could not produce a positive and effective concretizatio

Chapter II

The Evolution of Technical Reality: Element, Individual and Ensemble

I: Hypertelia and Self-Conditioning in Technical Evolution

The evolution of technical objects manifests certain hypertelic phenomena which endow each technical object with specialization, which causes it to adapt badly to changes, however slight, in the conditions of its operation or manufacture. The system that constitutes the essence of the technical object can, in effect, be adapted in two ways. First, it can be adapted to the material and human conditions in its production: each particular object can make the best possible use of the electrical, mechanical or even chemical characteristics of the materials of which it is made. For example, a pump suitable for a cold country may not be at all suitable for a hot country, and vice versa; an aeroplane made for high attitudes may have difficulties, especially in landing and taking off, if it has to operate for a short period at low altitudes. The jet engine, whose principle of propulsion makes it superior to the propeller engine at high altitudes, does not work well at low altitudes. The great speed attained by a jet plane becomes a crippling factor in terms of ground contact, because a reduction in lifting surface coupled with the use of a jet engine makes it necessary to land at high speed (at more or less the cruising speed of a propeller plane) and this creates the need for a very long landing strip.

Early aeroplanes, which could land in the open country, were less overadapted functionally than modern planes. Functional overadaption can go so far as to eventuate in systems resembling symbiosis and parasitism in biology. Some small planes cannot easily take off unless they are launched by a larger plane. Others use rockets to increase their power of ascent. The transport glider is an example of a hypertelic technical object; it is nothing if not an air freighter or, better still, an air barge without a "tugboat", and in this it is quite different from an ordinary glider which, following a simple launching, can avail of air currents to stay aloft on its own. The autonomous glider is very well adapted to engineless flight, while the transport glider is merely one of two asymmetrical partners in a technical whole whose other half is the towing vessel. For its part, the towing vessel is not well adapted because on its own it is incapable of carrying a load proportional to its own power.

We can say, therefore, that there are two kinds of hypertelia, one of which is well adaptable to determined conditions without involving the slightest division of the technical object or any loss of autonomy, the second of which involves a division of the technical object, as is the case in the division of a primitive technical being into towing unit and unit towed. In the first case the autonomy of the object is preserved, in the second it is sacrificed. We find a mixed hypertelic case in a situation involving adaptation to environment, where the object requires a particular environment in order to work properly, because of its being paired energetically with its milieu. This case is pretty well identical to that involving a division into towing and towed units. For example, a clock that is synchronized to a particular electrical circuit will not be able to function if it is transported from France to America because of the difference in frequency (60 Hertz and 50 Hertz respectively). An electric motor requires an electric circuit or a generator. A single-phased, synchronous motor can be more satisfactorily adapted to a particular milieu than a universal motor: within the chosen environment it works much better, but outside of that environment it is worthless. A triple-phase synchronous motor is even more adaptable to working on a particular type of electrical circuit than is a single-phase motor, but it can't be used with any other kind of circuit. By means of this limitation, it functions much more satisfactorily than does the single-phase engine: it has a better control system and better output and it is subject to very little wear and to very slight losses in connecting lines.

Adaptation to technical environment is of fundamental importance in certain cases. The use of triple-phase alternating current, for example, is perfect for factory engines of whatever capacities. As opposed to this, up to now it has not been possible to use triple phase alternating current to drive electric trains. It is necessary to have recourse to a transfer system that connects and adapts the train-engine's current to the network of high tension, triple phase, alternating current. This is done either by sub-stations that provide continuous voltage to the feeders of the overhead wires or by transformers and adaptors on board the train itself supplying the engine with continuous voltage from overhead wires that are powered with alternating current. Indeed, if the engine had to adapt itself to energy distribution network in terms of both energy and frequency it would lose too great a part of its range of use. Whether synchronized or unsynchronized, an engine cannot supply a large amount of mechanical energy until it reaches its working speed. However satisfactory this may be for a fixed machine, such as a lathe or a drill, which starts without any load and does not encounter any resistance until it reaches maximum speed, the train engine does not work in this fashion. The train engine starts with full load and with all the inertia of the train it hauls. If it is at all admissable to speak of the working speed for a locomotive, we can say that the locomotive is least able to provide energy when it reaches its working speed; it has to supply maximum energy in transitional stages such as acceleration and deceleration or counter-current braking. Such a mode of operation, with its many frequent adaptations and changes in power is quite different from that reduction of the range of systems of operation that typifies adaptation to the technical environment, as in the case of the factory with its polyphase electric circuit of constant frequency. The example of the traction engine enables us to understand that the existence of the technical object is sustained by a double relationship--a relationship with its geographic environment on the one hand, and with its technical environment on the other.

The technical object stands at the point where two environments come together, and it ought to be integrated into both these environments at the same time. Still, these two environments are two worlds that do not belong to the same system and are not necessarily completely compatible with each other. Hence, the technical object is delimited to a certain extent by human choice which tries to establish the best compromise possible between these two worlds. The traction engine, in one sense, resembles a factory engine in that it receives its power from high tension, triple phase, alternating lines. In another sense altogether it is a device that expends its energy in hauling a train from a dead stop to full speed and then, by diminishing degrees of speed, to a stop once again; it has to haul the train up ramps, around corners, and down slopes, maintaining the most constant speed possible in all of this. The traction engine doesn't simply transform electrical energy to mechanical energy; it applies electrical energy to a geographically varied world, translating it technically in response to the profile of the railway track, the varying resistance of the wind, and to the resistance provided by snow which the engine pushes ahead and shoves aside. The traction engine causes a reaction in the line that powers it, a reaction that is a translation of the geographical and meteorological structure of the world. There is an increase in the absorbed intensity and a decrease in line voltage when snow becomes deepest, when the slope becomes more acute, and when lateral wind increases friction by pushing the wheel flanges against the rails. The two worlds act on one another through the traction engine. Such is not the case with a triple-phase factory engine, which does not effect a causal relationship between the technical world and the geographic in any such manner; its operation is almost totally confined within the technical world. Because of its singleness of milieu, the factory engine does not have to be adapted to its environment, whereas the traction engine needs an environment of adaptation, which is composed of repressors located in the electrical sub-station or on the locomotive itself. All the factory engine needs by way of an environment of adaptation is a voltage-lowering transformer. Such a transformer could be done without in high powered engines; in engines of medium power it is needed as a precautionary measure, but this has more to do with human operators than with the job of environment adaptation.

There is a third case in which adaptation takes a different direction and has different significance, a case in which it does not lead at all so directly to hypertelic phenomena or to the consequences of hypertelia. Where there is need of adaptation not so much to environment in the strict sense but to the task of interrelating two environments, both of which are in a state of evolution, adaptation is limited and particularized in the direction of autonomy and concretization. This represents real technical progress.

Thus, the use of silicon sheet metal, which has a higher magnetic penetrability and a lower hysteresis than iron sheet metal has made it possible to lessen the weight and volume of traction engines while, at the same time, increasing their efficiency. A modification of this kind tends to mediate between the technical and geographical worlds, because a locomotive could have a lower centre of gravity as a result of the placing of the motors on the same level as the bogies; this would lessen the enertia of the rotor, and the significance of this for rapid braking would be appreciable. The use of silicon insulators has made possible a greater augmentation in heat without risk of insulator deterioration; this increases the possibilities of very high voltage to increase both starting torque and breaking torque. Modifications such as these extend rather than restrict the field of use for traction engines. A silicon-insulated engine could be used without extra precautionary measures on a locomotive that has to climb very steep slopes, and also in very hot countries. Its relational use becomes greater. The same kind of improved motor can be used (in small models) in the braking system of trucks. The engine becomes adapted to the relational modality primarily, rather than to the very special type of relationship which brings together electrical network and geographical world for the express purpose of hauling a train.

The Guimbal turbine[1] provides us with an analogous kind of concretization. This turbine is immersed in the water-pipe and is directly connected to a very small generator contained in a housing filled with oil under pressure. Here, the dam wall confines the whole power-house within the water-pipe, for all that appear at ground level are the enclosure containing the oil reservoir and the measuring dials. The water becomes plurifunctional. It supplies the energy that activates the turbine and the generator, and evacuates heat produced by the generator. The oil is just as notably plurifunctional. It lubricates the generator, insulates the gears, and conducts heat from gears to housing, where it is evacuated by the water. Also, it prevents water seepage through the axle-casing into the housing, because the oil pressure within the housing is greater than the water-pressure without. This very high pressure itself is plurifunctional. It effects permanent greasing under pressure in the bearings, while preventing seepage of water if the bearings are not quite watertight. At this point, we should note that the relational adaptation

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[1]These turbines are of a kind with those equipping "bulb-groups" in the new French tide-powered factories. They are reversible and, with a small expenditure of energy, they can be used to pump water at low tide.

under discussion is due to the plurifunctional nature of this concretization. Before Guimbal's invention, it was unthinkable to place the generator in the water-pipe containing the turbine, because even if all problems of watertightness and insulation could be imagined as solved, the generator was too big to be placed in a pipe. The method used to solve problems regarding watertightness and insulation made it possible to place the generator within the pipe by insuring improved cooling by means of both oil and water. One might even go so far as to say that the positioning of the generator inside the pipe is itself possible because the generator itself makes energy cooling possible at the very same time.

If the Guimbal generator were operated at full power in air it would quickly be ruined by heat, whereas there is no appreciable heat detected in its concentric double bath of oil and water, each of which is energetically stirred, the oil by generator rotation, the water by turbine turbulence. Here concretization is effected by an invention which supposes the problem solved. This particular concretization is only possible because of the new conditions erected by concretization. The only environment that tolerates non-hypertelic adaptation is the environment created by the adaptation itself. In this case, the act of adaptation is not really an act of adaptation in the sense we give the word when we define adaptation in terms of an environment which is already established prior to the process of adaptation.

The adaptation-concretization process is one which causes the birth of an environment rather than being the result of an already established environment. It is caused by an environment which had merely virtual existence before the invention. The invention happens because a jump is made and is justified by the relationship which is instituted within the environment it creates. The very existence of the possibility of the turbogenerator pairing is the realization of the same. It cannot have be geometrically situated inside the water-pipe unless there is some physical means of effecting thermic changes which make possible a reduction in dimensions. It could be said that concretizing invention brings into being a technogeographic environment (in this case, oil and water in turbulence) which is a condition upon which the possible functioning of the technical object depends. Therefore the technical object is the condition of itself as a condition for the existence of this mixed environment that is at once technical and geographical. This phenomenon of self-conditioning defines the principle by which it is possible to develop technical objects free of tendency towards hypertelia and disadaptation. Hypertelia arises when adaptation relates to a principle that existed prior to the process of adaptation. Adaptation of this kind makes as its goal conditions which always outstrip it, because it does not react on them and because it fails in its turn to affect them.

Progress in the evolution of technical objects is only possible if these objects are free to evolve and do not become subject to any necessity that leads towards fatal hypertelia. For this to be possible, the evolution of technical objects has to be constructive, that is to say, has to lead towards the creation of a third technogeographical environment in which every modification is self-conditioned. What is in question here is not progress conceived as a predetermined movement forward or as a humanization of nature; such a process could equally be thought of as a naturalization of man. Indeed, between man and nature there develops a technogeographic milieu whose existence is only made possible by man's intelligence. The self-conditioning of a system by virtue of the result of its operation presupposes the use of an anticipatory functioning which is discoverable neither in nature nor in technical objects made up to the present. It is the work of a lifetime to achieve such a leap beyond established reality and its system of actuality towards new forms which continue to be only because they exist all together as an established system. When a new device appears in the evolving series, it will last only if it becomes part of a systematic and plurifunctional convergence. The new device is the state of its own possibility. It is in this way that the geographical world and the world of already existing technical objects are made to interrelate in an organic concretization that is defined in terms of its relational function. Like a vault that is only stable once it has been completed, an object that has a relational function continues in existence and is coherent only when after it has begun to exist and because it exists. It creates its associated environment by itself and it achieves true individualization in itself.

II: Technical Invention: Form and Content in Life and in Inventive Thought

For the reasons already outlined, we can rightly state that the individualization of technical beings is the essential condition for technical progress. Such individualization is possible because of the recurrence of causality in the environment which the technical being creates around itself, an environment which it influences and by which it is influenced. This environment, which is at the same time natural and technical, can be called the associated milieu. By means of this the technical being is conditioned in its operation. This is no fabricated milieu, or at least it is not wholly fabricated; it is a definite system of natural elements surrounding the technical object and it is linked to a definite system of elements which constitute the technical object. The associated milieu is the mediator of the relationship between manufactured technical elements and natural elements within which the technical being functions. The ensemble constituted by oil and water in motion within and around the Guimbal turbine is of this sort. This ensemble is concretized and individualized by the recurring thermal changes that take place in it. The faster the turbine turns, the more the generator expels heat by Joule effect and magnetic loss. But the faster the turbine turns, the more the oil in the rotor and water around the housing increase in turbulence and activate heat exchanges between rotor and water. This associated milieu is the invented technical object's condition of existence. The only technical objects that, strictly speaking, can be said to be invented are those needing an associated milieu to make them viable. Indeed, they cannot be formed part by part in the course of a gradual evolution, because either they exist in their completeness or not at all. Technical objects which in their liaison with the natural world put into play what is essentially a recurrent causality must be invented rather than developed in stages, because such objects are the cause of their own condition of functioning. Such objects are viable only if the problem is resolved;

that is to say, only if they exist along with their associated milieu.

It is for this reason that so much discontinuity is noticeable in the history of technical objects with absolute origins. Previsionary and imaginatively creative thought alone can effect such a reversed conditioning in time. Elements that materially are to constitute the technical object, and that are independent one of the other, lacking an associated milieu that precedes the constitution of the technical object, must be organised in relation to one another by means of circular causality which will exist once the object is constituted. What is involved here, then, is a conditioning of the present by the future, or by what up to now does not exist. It is only very rarely that any such function of the future could be the result of chance. The reason for this is that this function depends upon a capacity for the organisation of elements in terms of requirements that are meaningful as a whole in terms of the goal towards which they aim and that act as symbols of a future ensemble as yet without existence. The unity of that future associated milieu in which causal relationships will be so deployed as to make possible the functioning of the new technical object is <u>represented or acted out</u> by systems of the creative imagination, in much the same way as an actor can play a role in the absence of the real person.

The dynamism of thought is like that of technical objects. Mental systems influence each other during invention in the same way as different dynamisms of a technical object influence each other in material functioning. The unity of the associated milieu of a technical object has an analogue in the unity of a living thing. During invention living unity is the coherence of mental systems that are arrived at because they exist in and are deployed in the same being; systems that are contradictory come into confrontation with and reduce each other. That which is alive can invent, because whatever is alive is an individual being that brings with it its own associated milieu. The ability to be self-conditioning is a principle of production capacity in self-conditioning objects. What escapes the attention of psychologists in their analysis of the inventive imagination is not so much the systems or forms or operations of this faculty, those elements that so immediately demand attention, as the dynamic background on which these systems confront each other and combine with each other, and with which they participate.

The Psychology of Form, clearly taking into account the function of totalities, attributes force to form. But, a more profound analysis of the imaginative process would undoubtedly reveal that the determining factor playing an energising role is not forms but that which supports form, that is, their background. However marginal it may always be in terms of our attention, the background is the harbour for dynamisms, and it is what gives existence to the system of forms. Forms interact not with forms but with their background, which is the system of all forms or, better still, the common reservoir of the tendencies of all forms even before they had separate existence or constituted an explicit system. The participational relationship connecting forms to their background is a relationship which straddles the present and brings the future to bear upon the present, that which brings the virtual to bear upon the actual. This is so because the base is a system of virtualities, of potentials, and of moving forces, whereas forms are a system of the actual. Invention is a taking into account of the system of actuality by a system of virtualities; it is the creation of a new system from these two.

Forms are passive to the extent that they represent actuality. They become active when they are organised in relation to their base, and thus bring to actuality former virtualities. It is undoubtedly very difficult to clarify those modalities by which a forms system relates to a background of virtualities. All we can say is that it happens in much the same manner of causality and conditioning as that by which each of the structures in a constituted technical object relates to the dynamisms of its associated milieu. These structures are in the associated milieu, and they are influenced by it and, through it, by the other structures of the technical being. They exert a partial influence on it in turn, while the technical milieu, which is influenced by each structure individually, influences them all together by supplying them with energetic, thermal, and chemical conditions of functioning. There is a recurrence of causality between associated milieu and these structures, but this is not a symmetrical recurrence. The milieu plays an informational role. It is a basis for self-regulations, and it is a vehicle for information or for information-controlled energy (for example, water shaken at a certain speed cooling a housing at a certain rate). The associated milieu, on the other hand, is homeostatic and the structures are affected by a non-recurring causality, each of them going in its own direction.

Freud analysed the influence of background on form in psychic life. He interpreted it in terms of the influence of hidden forms on explicit forms; hence the notion of suppression. The existence of symbolization has indeed been demonstrated (experiments on a hypnotised subject to whom a violently emotional scene is described and who, on waking up, uses symbolic transposition in his account of the scene), that the unconscious is populated by forms comparable to explicit forms has not been demonstrated. The dynamic of tendencies is sufficient to explain symbolization if we accept as efficacious the existence of a psychic background on which are deployed, and which is influenced by, explicit forms which the conscious and waking state shows forth. The environment associated with the systematic of forms establishes recurrent causal relationships between forms and causes reorganizations of the system of forms taken in its totality. Alienation is a rupture between background and forms in psychic life. It occurs when the associated milieu no longer effectively regulates the dynamism of forms. The reason why the imagination has never been properly analysed up to the present day is that forms have been accorded an active role and have been considered to take the initiative in both psychic and physical life.

In reality, there is a strong kinship between life and thought. In a living organism all living matter cooperates with life. The most obvious and clearly defined structures in the body are not the only ones with life initiative; blood, lymph and conjunctive tissues play their part in life. An individual is not only made of a collection of organs joined together in systems. He is composed too of something that is no organ and that is not a structure of living matter in the sense of forming an associated milieu for the organs. Living matter serves as background for the organs in that it connects them one to another and makes then into an organism. It preserves the fundamental chemical and physical equilibriums on which the organs exert sudden, though limited, variations. The organs participate in the body. Living matter is far from being pure indetermination or pure passivity. Neither is it a blind tendency; it is, rather, the vehicle of informed energy. In similar fashion, thought comprises precise and distinct structures such as representations, images, memories and perceptions. But all these elements relate to a background which gives them direction and homeostatic unity and conveys informed energy from one to the other and from all to each. We might say that the background is axiomatic that is implicit. New systems of forms are elaborated in it. Without a background of thought, there can be no thinking being but only a unconnected series of discontinuous representations. Their background is the mental associated milieu of forms. It is the middle term between life and conscious thought just as the environment associated with the technical object is a middle term between the natural world and the technical object's fabricated structures. We are able to create technical beings because we have within ourselves an interplay of relationships and a matter-form association which is remarkably analogous to that which we establish in the technical object. The relationship between thought and life is analogous to the relationship between a structured technical object and the natural environment. The individualized technical object is an invented object, one that is a product of the interplay of recurrent causality between life and thought in man. An object that is associated either with life or thought alone is a utensil or tool rather than a technical object. It has no internal consistency, because it has no associated milieu to institute recurrent causality.

III. Technical Individualization

The principle that recurrent causality individualizes a technical object in its associated milieu makes it possible for us to consider all the more clearly certain technical ensembles and to know whether we should treat them as technical individuals or as an organized collection of individuals. We may say that a technical individual is one having an associated milieu as a sine qua non condition of its functioning. The opposite is true of an ensemble. In the case of a laboratory such as a laboratory for the study of the psychology of sensations, one might ask if an audiometer is a technical individual. If we consider it apart from power supply circuits and the earphones or microphones that are its electroacoustic conductors, the answer is no. The audiometer is defined as having to be placed in certain conditions of temperature, voltage, and noise-level so that stable intensities and proper measurement of thresholds are possible. The room's coefficient of absorption and its resonances at various frequencies have to be taken into account. The locale is part of the whole apparatus. The audiometer has to be operated either in flat, open country or else measurements must be taken in a sound-proof room with microphonic floor suspension and walls heavily covered with glass wool. What, we might ask, is an audiometer essentially, regardless of whether it is factory-made or home-made? It is an ensemble of technical forms with relative individuality. For example, it has two high-frequency oscillators, one of which is fixed, the other variable. Whichever of the two frequencies has the lower beat is the one producing the audible sound. An attenuator makes it possible to regulate the intensity of stimuli. Neither of these oscillators is alone a technical object because in order it be stable it requires stabilized heater voltage and anode voltage. Generally, this stabilization is obtained by means of a recurrent causality electronic system which functionally constitutes the associated milieu of the technical forms of oscillators. However, what I have called an associated milieu is not quite that. It is, rather, a transfer system, a means of adaptation allowing the oscillators not to be influenced by the external technical and natural environment. It could not be a true associated milieu unless a chance frequency drift in one of the oscillators led to a variation in the supply-current that works against such a drift. This would involve an exchange between regulated supply and oscillators through reciprocal causality. The ensemble of technical structures would be self-stabilized, whereas here the opposite happens: only the supply is self-stabilized and does not react to chance variations in the frequency of one of the oscillators.

There is a great practical and theoretical difference between these two cases. Indeed, if only the supply is stabilized without any connection of recurrent causality with the oscillators, other uses of the power supply at the same time could be limited or extended without inconvenience. For example, one can plug in a third oscillator to the same supply without interfering with its operation, as long as normal limits of output are not exceeded. On the other hand, if one wishes to get an effective retroactive regulation, one must have no more than one single structure attached to a single associated milieu. Otherwise, chance variations opposite in direction to the two structures that are not synergetically connected to the same associated milieu could balance each other and fail to lead to a regulatory reaction. Structures connected with one single associated milieu should operate synergetically. Therefore, the audiometer comprises at least two distinct parts that cannot be self-stabilized by the same associated milieu--the first, the frequency generator, the second, the amplifier-attenuator. One of these ensembles cannot be allowed to act upon the other, so the two connecting leads must be carefully separated and, in order to prevent interaction of any kind, the partition separating them must be electrically and magnetically screened. On the other hand, the material limitation of the audiometer is not a functional limitation. The amplifier-attenuator is normally extended by the acoustic reproducer, or by the room, or by the outer ear of the subject, depending on whether connection with the subject is made by loud-speaker or earphones. Consequently, it is possible to postulate the existence of relative levels of individualization in technical objects. This criterion has an axiological value: the coherence of a technical ensemble is maximal when the ensemble is made up of two sub-systems with the same level of relative individualization. So, in a laboratory for the study of the psychology of sensations it would not be advantageous to group together the amplifier-attenuator and the two oscillators of the audiometer. There would be an advantage, however, in grouping the two oscillators so that they could respond at the same time and to the same degree to current or temperature variation, so that the lower beat-frequency resulting from these two correlative frequency variations in each oscillator are reduced as much as possible, assuming that both the fundamental frequencies rise and fall together. As opposed to this, it would be totally contrary to the functional unity of the beat-frequency generator to have two separate power supplies and to connect the power supply of one oscillator with one phase of the circuit and the second with the other phase. This would upset the effect of self-stabilization because it would compensate for the two variations which give the ensemble of the two oscillators stability in low-beat frequencies. Still, it would be useful to plug the oscillators into a different power-phase than the one to which the amplifier-attenuator is attached: this would prevent the supply voltage of the oscillators from reacting to variations in anode consumption by the amplifier.

The principle of the individualization of technical objects in an ensemble is a principle of sub-ensembles with recurrent causality in their associated milieu. All technical objects with recurrent causality in their associated milieu should be separated from each other and should be connected in such a way as to preserve the mutual independence of their associated milieux. Hence, the respective sub-ensembles of oscillators and amplifier-attenuator-reproducer should be independent of each other in power supply and in their coupling. Amplifier intake should high in relation to oscillator outlet, so as to insure that oscillator reaction to the amplifier is as slight as possible. If, for example, the attenuator were connected to the outlet of the oscillators, adjustment of the attenuator would react on the frequency of the oscillators. An ensemble of higher degree which comprises all these sub-ensembles is defined by its capacity to effect various free relationships without destroying the autonomy of individualized sub-ensembles. This is the part played by a general connection command panel in a laboratory. Electrostatic and electromagnetic screening and the use of non-reactive couplings such as the cathode-follower are designed to maintain the independence of sub-ensembles while allowing for the various necessary combinations between sub-ensemble functions. The availing of the benefits of functioning without any interaction between conditions of functioning is a secondary functional role of the ensemble called the laboratory.

We might ask, then, at what level individuality exists. Does it exist at the sub-ensemble or ensemble level? The answer must as usual be given in terms of the criterion of recurrent causality. Indeed at the higher ensemble level (that of the factory, for example) there is really no associally milieu. If there is, it exists in only certain respects, and has no existence of a general nature. As an example, to have oscillators in a room where an audiometry experiment is being done is often bothersome. If the oscillators use transformers with magnetic circuits made of iron, magnetostriction* in the laminations leads to a vibration that emits a disturbing sound. An oscillator with resistors and capacitators also gives off a weak sound as a result of alternating electric attractions. In order to conduct delicate experiments, it becomes necessary either to place the apparatus in a different room and to operate them by remote control or to isolate the subject in a soundproof room. Likewise, magnetic radiation in power transformers can greatly interfere with amplifiers in electroencephalographic and electrocardiographic experiments. That higher ensemble which is the laboratory is therefore made up of non-connected devices thereby preventing the chance creation of associated milieux. The difference between ensemble and technical individuals lies in the fact that for the ensemble the creation of a unique associated milieu is undesirable. The ensemble comprises a certain number of devices that prevent any possibility of the creation of a unique associated milieu. It prevents the interior concretization of the technical objects it contains and only makes use of the results of their operation without allowing for any interaction of what conditions them.

Below the level of technical individuals, are there any groupings with some degree of technical individuality? Yes, but the individuality they possess is not structured like that of technical objects with an associated milieu. Its structure is like that of a plurifunctional composition that lacks a positive associated milieu; that is to say, without self-regulation. Let us take the case of hot-cathode tube. As soon as this tube is placed in a lay-out with automatically polarised cathode resistance it becomes the centre of phenomena of self-regulation. If the heater voltage increases, for example, there is an increase in cathode emission and this leads to an increase in negative polarisation. The tube no longer increases amplification and output scarcely rises, and the same is true of its anode dissipation. A similar phenomenon in Class A amplifiers* is responsible for stable levels of output despite variations in levels of input in the amplifier. But such regulatory counter-reactions are not centred only in the interior of the tube. They depend upon the ensemble of the layout and, in certain kinds of fixed layouts, they do not exist at all. Thus, a diode whose anode heats up conducts in both directions, and this increases the intensity of the current that goes through it. The cathode, receiving the electrons coming from the anode, becomes increasingly hot and, accordingly, gives off an increasingly greater number of electrons. This destructive process is therefore an example of positive circular causality which belongs to the whole layout and not solely to the diode.

Infra-individual technical objects can be called technical elements. They differ from true individuals in the sense that they have no associated milieu. They can be integrated into an individual. A hot-cathode tube is more a technical element than a complete technical individual. It can be compared to an organ in a living body. In this sense it would be possible to define a new science of general organology. This science would involve the study of technical objects at the level of the element. It would be part of the science of technology, including mechanology, whose subject of study would be complete technical individuals.

Section IV: Evolutive Chains and Technicity Conservation. The Law of Relaxation

The evolution of technical elements can have reverberations in the evolution of technical individuals. Technical individuals, composed as they are of elements and associated milieu, depend to some extent on the characteristics of the elements which they use. Today, for example, electric magnetic engines can be much smaller than was possible in Gramme's day because their magnets are much smaller. In some cases the elements are as it were the crystalization of an earlier technical operation that produced them. Thus, magnets with set bushings, which are still called magnetically hardened magnets, are produced by a process that consists in keeping a strong magnetic field around the melting mass which, once cooled, will be the magnet. Thus, magnetization of the mass begins above the Curie point,* then the same intense magnetization is continued during the cooling of the mass. When the mass is cold, it is a much more powerful magnet than it would have been had it been magnetized after cooling. All this happens as if the strong magnetic field caused a fixing of the molecules in the melting mass. This fixing continues after cooling if the magnetic field is preserved during cooling and solidification. Now the furnace, crucible and coils creating the magnetic field constitute a system which is a technical ensemble. The furnace heat should not affect the coils and the field of induction creating heat in the melting mass should not neutralize the continuous field designed to produce magnetization. This technical ensemble is itself made up of a number of technical individuals that are arranged in terms of the result of their functioning and in such a way that they do not interfere with the conditioning of their particular functioning. So, in the evolution of technical objects we witness a causal development from earlier ensembles to later elements. When these elements are introduced into an individual and modify its characteristics, they make possible a progression in technical causality from the level of elements to the level of individuals and thence to the level of ensembles. Thence, in a new cycle, technical causality, by a process of fabrication, goes back once again to the level of elements and there becomes reincarnated in new individuals and, later, in new ensembles. Thus, there exists a line of causality which is serrated rather than rectilinear, in which the same reality exists first in the form of element and then with characteristics of an individual and, finally, with the characteristics of an ensemble.

A historical solidarity exists in technical realities. The fabrication of elements is the intermediary that transmits it. If any technical reality is to have posterity, it is not enough that it be improved in itself; it must also be reincarnated and must participate in a cycle of becoming in accord with a formula of relaxation in levels of reality. The solidarity of technical beings in relation one to the other in the present generally tends to obscure a much more essential solidarity, one which requires a temporal evolutionary dimension but is not identical to biological evolution because it happens along continuous lines and scarcely ever involves successive changes in level. Transposed into biological terms, technical evolution consists in this, that if a species produced an organ, if the organ were given to an individual, it would thereby become the first term of a lineage which in turn produces a new organ. In life an organ cannot be detached from a species; in technics an element is detachable from the ensemble that produced it for the very reason that it is fabricated; therein lies the difference between a product and something engendered. So, the technical world has a historical as well as a spatial dimension. Its solidarity at a given moment should not obscure its successive solidarity. Indeed, the latter is responsible for the major stages or periods of technical life because of its law of serrated evolution.

The law of relaxation has no corresponding rhythm elsewhere. Neither the human nor geographic worlds are capable of producing oscillations of relaxation with successive bursting and spouting forth of new structures. The time of relaxation is the real technical time. It can become more dominant than all other aspects of historical time, to the extent that it can synchronize all other rhythms of development and appear to determine the whole technical evolution, whereas in fact it merely synchronizes and induces evolutive phases. We may take the evolution of energy sources since the eighteenth century as an example of evolution according to a rhythm of relaxation. A large part of the energy used in the eighteenth century came from waterfalls, from air displacements in the atmosphere, and from animals. These kinds of driving power were availed of for artisinal exploitation or in restricted mills here and there along the water-course. From these mills there developed, early in the nineteenth century, thermodynamic machines of much greater efficiency. Another development was the modern locomotive which resulted from the adaptation to the Marc Seguin boiler, which was lighter and smaller than the distiller boiler, of Stephenson's sliding panel, which made it possible to have variation in the relationship between time of admission and time of expansion, first of all, and, then, made it possible to exploit the dead point in order to move into reverse gear (steam reversal). This invention, which is of an artisanal sort, and which made possible the adaptation of the traction engine to great range of contours, with great variation in torque, at the slight cost of a loss in output in systems of very high frequency only (ones in which admission time equals total driving time), makes thermal energy easily adaptable to rail haulage. The Stephenson slide-panel and the tubular boiler, elements which emerged from the artisinal ensembles of the eighteenth century enter into the forms of the new individuals of the nineteenth century, particularly into the form of the locomotive. The transportation of large tonnage across terrains of all sorts became possible and, since following contour lines and the meanders of navigation channels was no longer necessary, this led to nineteenth century industrial concentration, which is essentially thermodynamic in its structures, as well as incorporating individuals with thermodynamically-based principles of function. There the great industrial ensembles of the nineteenth century at its apogee were concentrated around such sources of thermal energy as coal-fields or around places where there was greatest use of heat energy, such as coal-mines and iron foundries. The route of progression was from thermodynamic element to thermodynamic individual and from thermodynamic individuals to the thermodynamic ensemble.

The principal aspects of electrotechnics appear as elements produced by thermodynamic ensembles under discussion. Before they become autonomous, the applications of electric energy appear as very flexible means of energy transmission from place to place by means of power lines. Metals with high magnetic permeability are elements produced by applications of thermodynamics in metallurgy. Copper cables and high resistance porcelains for insulators emerge from steam-powered wire mills and coal furnaces. The metallic framework of pylons and concrete for dams come from great thermodynamic concentrations and, as elements, they enter into those new technical individuals, turbines and alternators. So, a new height and new concentration of beings is arrived at and concretized. In the production of electric energy Gramme's machine makes way for the polyphase alternator. The continuous currents of the first energy transmitters make way for alternating currents of constant frequency that are adaptable to production by heat turbine and, consequently, by hydraulic turbine too. These electrotechnical individuals have been integrated into ensembles for the production, distribution, and use of electric energy, ensembles whose structure differs greatly from that of thermodynamic concentrations. The role once played by the railway in thermodynamic concentraturs is taken over, in the ensemble of industrial electricity, by high tension transmission lines.

The moment electrical technics reach their full development, they produce as elements new systems which begin a new phase. First of all particle-acceleration is achieved, initially by electric fields, then by continuous electric fields and alternating magnetic fields and, because the possibility of exploiting nuclear energy is discovered by this means, it leads to the construction of technical individuals. The next thing that happens is that, quite remarkably, the possibility of discovering, thanks to electrical metallurgy, metals such as silicon which permit a transformation of the radiant energy of light into electrical current, with an output that attains significant ratio for limited applications (6%), an output not much lower than that of the first steam-engines. The pure silicon photocell, a product of the great industrial electronic ensembles, is one element that as yet has not been incorporated into a technical individual. Up to now it is no more than an object of curiosity situated at the extreme point of possibilities in the electrometallurgy industry, but it could be a starting point for a phase of development similar to the familiar and still incomplete development phase in the use of industrial electricity.

Now each phase of relaxation is capable of effecting a synchronization of minor or equally important aspects. For example, developments in thermodynamics went hand in hand with developments in coal transport and railway passenger service and, again, developments in electrotechnics parallelled those in transportation by automobile. Even though in principle the automobile is thermodynamic, it uses electric energy as an essential auxiliary system, particularly for lighting purposes. Long-distance transport of electric energy made possible an industrial decentralization that needs the automobile as a correlative means of transporting human beings between various places and altitudes, regardless of whether or not there is rail service in the same areas. The automobile and the high-tension line are parallel technical structures which are synchronized but not identical. At the present moment, the automobile industry cannot fully avail of electric energy.

Similarly, there is no relationship between nuclear energy and energy obtained by photoelectric effect. Still, these two forms are parallel and can be synchronized.[1] For example, in all likelihood it will prove impossible to make use of nuclear energy for limited applications such as those requiring a few dozen watts; on the other hand, photoelectric energy does lend itself to decentralization. Photoelectric energy is essentially decentralized in production, while nuclear energy is essentially centralized. The kind of relationship that existed between electric energy and energy extracted from petrol combustion now obtain between energy of nuclear origin and energy of photoelectric origin, though the differences are more pronounced.

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[1]And they can be joined together; a photocell can be irradiated by a radioactive source.

V. Technicality and the Evolution of Technics: Technicality as an Instrument of Technical Evolution

The different aspects of the individualization of the technical being constitute the centre of an evolution that proceeds by successive steps, but that is not dialectic in the proper sense of the term because in this instance the role of negativity is not to be a progress-promoting factor. Negativity in the technical world is a flaw in individualization, an incomplete meeting of the technical world and the natural world. Negativity does not promote progress. Rather, it promotes change because it spurs man to look for new and more satisfactory solutions than those he has. But this desire for change does not directly affect the technical being. It only affects man as inventor and user. Furthermore, the change in question should not be mistaken for progress. A too rapid change works against technical progress because it interferes with the transmission of what one age bequeathes to the next in the form of technical elements.

If technical progress is to occur, each age has to pass on to its successor the fruit of its technical endeavour. What can be transmitted from age to age is not technical ensembles or individuals but the elements that these individuals grouped as ensembles were able to produce. Indeed, because of their capacity for internal intercommutation, technical ensembles can go outside of themselves, producing elements different from their own. Technical beings differ from living beings in a great number of ways, but they differ essentially in this respect: a living being engenders other beings that are similar to itself or that can become like it after a certain number of successive reorganisations that occur spontaneously if the conditions are suitable; the technical being is different in that it lacks this capacity; it cannot produce other technical beings like itself, despite the efforts of cyberneticians who have tried to make technical beings copy living beings in constructing beings similar to themselves. That is impossible at the present time except in an imaginary and baseless way. But the technical being has a wider scope than the living, and this is made possible by an infinitely smaller advancement: the technical being can produce elements that retain the degree of perfection attained by a technical ensemble and can be brought together to make possible the constitution of new technical beings in the form of individuals. This is a case not of begetting or procession or direct production but of indirect production through the constitution of elements that have within them a certain degree of technical perfection.

This affirmation calls for a detailed explanation of what we mean by technical perfection. From an empirical and external point of view, it can be said that technical perfection is a practical quality or, at the very least, the material and structural support for certain practical qualities. For example a good tool is not merely a well made and well shaped tool. An adze can be in bad condition and poorly sharpened and yet, from a practical point of view, be a good tool. An adze is a good tool if, on the one hand, its curve is suitable for a clean and well-directed stroke on the wood and, on the other, if it takes and keeps a keen edge even when it is used on hard woods. Now this last quality is a product of the technical ensemble that produced the tool. The adze, as a manufactured element, can be made of a metal whose make-up varies at different points. This tool is not merely a block of homogeneous metal shaped according to a particular form. It has been forged, which means that the molecular chains in the metal have a certain orientation that varies in different places, like a wood with fibres so disposed as to give the greatest solidarity and the greatest elasticity. This is particularly the case in middle parts between the cutting edge and the flat part and between the socket and the cutting part of the blade. The area close to the cutting edge is elastically deformed during work because it acts as a wedge and as a lever on the wood-chip as it is being removed. Indeed, the cutting end is tempered more than all the other parts; and it must be well-tempered, though in a carefully delimited way, for otherwise a too great weight of metal would render the tool breakable and the cutting edge would shatter. It is as if the tool as a whole were made up of a plurality of differently functioning zones soldered to each other. The tool is not made of matter and form only. It is made up of technical elements arranged for a certain system of usage and assembled into a stable structure by the manufacturing process. The tool retains within it the result of the functioning of a technical ensemble. The production of a good adze requires a technical ensemble of foundry, forge, and tempering.

The technicality of the object is, therefore, more than a quality of usage. It is that in the object which is added to an initial design determined by the relation of form to matter. It is, as it were, an intermediary between form and matter; for example, in the case of the adze, the progressive heterogeneity of tempering at certain points. Technicality is the degree of concretization in an object. The concretization in question is what, in the days of wood foundry, made for the worth and fame of Toledo blades and, lately, the quality of Saint-Etienne steels. These steels are an expression of the functioning of a technical ensemble which included the characteristics of the coal used as much as the temperature and chemical composition of non-chalky Furens waters, or the essential elements of the green wood used for the stirring and refining of the molten metal prior to casting. In certain cases, technicality becomes preponderant in relation to the abstract characteristics of the matter-form relationship. Thus, in matter and form a helicoidal spring is a very simple thing. Yet, the manufacturing of springs requires a high degree of perfection in the technical ensemble producing them. Quite often, the quality of individuals such as a motor or amplifier is dependent more on the technicality of simple elements (valve springs or a modulation transformer, for instance) than on the sophistication of the assembly. Also, technical ensembles capable of producing such simple elements as a spring or transformer are sometimes extremely large and complex, almost coextensive with all the ramifications of many worldwide industries. There would be no exaggeration in saying that the quality of a simple needle expresses the degree of perfection of a nation's industry. This is the reason for the fairly legitimate existence of judgments of the sort that define a needle as "an English needle." Judgments such as these make sense because technical ensembles are reflected in the simplest elements they produce. One can't deny that there are other, less legitimate reasons for this sort of thinking, particularly because it is easier to qualify a technical object in terms of its origin than to make judgments on the basis of its intrinsic value. This is a phenomenon of opinion; but this phenomenon, however much it may give rise to exaggerations or to intentional misinformation, is not without foundation.

Technicality can be regarded as a positive characteristic of an element, as analogous to the self-regulation brought about in a technical individual by its associated milieu. At the element level, technicality is concretization. It is what makes an element produced by an ensemble really an element rather than an ensemble or individual. This peculiarity makes it detachable from the ensemble and frees it for the composition of new individuals. There is no peremptory reason, admittedly, technicality to the element alone. At the individual level, the associated milieu is a depositary of technicality, as is the scope of intercommutativity on the ensemble level. Still, it is proper to reserve the term, technicality, for that quality of the element which is the expression of what the technical ensemble has acquired, and preserves, and will send forward into a new period. The element carries forward technical reality, whereas the individual and the ensemble contain technical reality without being able to transport and transmit it. They can produce and preserve but not transmit. Elements have a transductive property that makes them the true carriers of technicality, just like seeds that carry along the properties of a species and are to remake new individuals. Therefore it is in elements that we find technicality at its purest or, as it were, in a free state; in individuals and ensembles we can find it only in a state of combination.

Now the technicality carried by elements does not comprise negativity, and no negative conditioning comes into play at the moment of the production of elements by ensembles or at the moment when individuals are produced by invention, which brings elements together to form individuals. Invention, which is the creation of an individual, presupposes an intuitive knowledge of the technicality of elements in the inventor. Invention takes place on a middle level between the concrete and the abstract, the level of diagrams, which implies an earlier existence and a coherence for its representations--those images that mask technicality with a layer of symbols which are part of an imaginary methodology and imaginary dynamics. Imagination is not only a faculty for inventing or creating images beyond the bounds of sensation. It is also a capacity for perceiving in objects qualities that are not practical, qualities that are neither directly sensory nor wholly geometric, qualities that have to do neither with pure matter nor pure form but belong to the in-between level of systems.

The technical imagination may be considered as defined by a particular sensitiveness to the technicality of elements that paves the way for the discovery of possible connections. The inventor does not proceed ex nihilo, beginning with matter to which he gives form; he begins with elements that are already technical and then discovers an individual being that is capable of incorporating them. The compatibility of individuals in a technical individual implies an associated milieu. Therefore the technical individual should be imagined, that is to say, it should be assumed to be constructed, as an ensemble of organized technical systems. The individual is a stable system of technicalities of elements organized into an ensemble. What is organized is these technicalities; the elements also are organized, but only in so far as they are bearers of these technicalities and not because of anything that has to do with their own materiality. An engine is an assemblage of axles and volumetric systems, each defined by its characteristics and technicality rather than its materiality; also an element of indetermination can subsist in the placing of any one element in relation to the others. The place for some elements is chosen more for extrinsic than intrinsic considerations about the single technical object in relation to the various processes of its operation. Intrinsic determinations based on the technicality of each of the elements are those that constitute the associated milieu. And the associated milieu is the concretization in mutual relationship of the technicalities borne by all the elements. These technicalities can be conceived of as stable conduits reflecting the characteristics of the elements rather than as simple qualities. They are forces in the fullest sense of the word; that is to say, they are capacities for producing or undergoing an effect in a fixed manner.

The more advanced the technicality of an element becomes, the more the margin of indetermination of this force diminishes. This was what I wanted to state when I said that the elementary technical object becomes concrete according as its technicality increases. This force could also be called capacity, as long as it is understood that it is being characterized with reference to a fixed use. Generally speaking, the more advanced the technicality of an element becomes, the larger becomes the scope of its conditions of use, because of the great stability of the element. Thus, the technicality of a spring increases when it can withstand higher temperatures without loss of elasticity and preserve, without critical modification, its coefficient of elasticity within more extensive thermal and mechanical limits; technically, it remains a spring within larger limits and is suitable for less restricted limits of incorporation into any kind of technical individual. An electrolytic condenser* has a lesser degree of technicality than a dry dielectric condenser such as paper or mica. In fact, a electrolytic condenser has a capacity that varies as a function of the voltage to which it is submitted; its thermal limits of use are narrower. At the same time it varies when subjected to constant voltage because the electrolyte, like electrodes, becomes chemically modified in the course of functioning. Dry dielectric condensers, on the other hand, are more stable. Still, here once again the quality of technicality improves with the independence of characteristics in relation to conditions of utilization. A mica condenser is better than a paper condenser; the vacuum condenser is best of all, because it is not even subject to the condition of voltage limit arising where there is risk of perforating the insulator. At the in-between level, the silvered-ceramic condenser, which varies very little with temperature, and the air condenser too provide a very high degree of technicality.

In this respect, it should be pointed out that there is no necessary correlation between the commercial price of a technical object and its elementary technical quality. Very often, considerations of price have not absolute influence though they may exert some influence through other requirements such as place. Thus, an electrolytic condenser is preferable to a dry dielectric condenser where a greater capacity would demand too great a bulk for housing the condenser. Likewise, an air condenser is very bulky compared with a vacuum condenser of the same capacity. Yet it is much cheaper and in a dry atmosphere it is every bit as reliable in operation. Therefore economic considerations ~~is~~ are indirectly influential in a great number of cases, in terms of the repercussions of the object's degree of concretization upon the object's operation in its individual ensemble. What is influenced by economic repercussions is the general formula of the individual being rather than the element as element. The liaison between the technical and economic fields is created at the level of individual or ensemble, but only very rarely at the element level. For this reason, we can say that to a very great extent technical value is independent of economic value and can be evaluated according to independent criteria.

The transmission of technicality by elements establishes the possibility of technical progress over and above the apparent discontinuity of forms, fields and kinds of energy used and, occasionally, of systems of functioning. Every stage of development is a legatee of earlier eras and progress is all the more certain the more completely and perfectly it tends towards the state of sole legatee.

The technical object is not, strictly speaking, a historical object; over the course of time it is influenced only insofar as it is a vehicle for technicality, or insofar as it plays a transductive role between one age and the next. Neither technical ensembles nor technical individuals last. Elements alone have the power to transmit technicality from era to era in a form that is realized, complete and materialized in a product. For this reason it is proper to analyse the technical object as composed of technical individuals. But it must be made clear that at certain moments in its evolution the technical object is significant on its own account and is a depositary of technicality. In this regard, it is possible to base an analysis of the technics of a human group on an analysis of the elements produced by their individuals and ensembles. Often, these elements alone are able to survive the ruin of a civilization and persist as good witnesses to a state of technical development. From this point of view, the method used by ethnologists is perfectly valid; but its application could also be extended to analyse the elements produced by industrial technics.

There is no fundamental difference between peoples that have no industry and peoples whose industry is well developed. Technical individuals and technical ensembles exist even among peoples who have no industrial development; nevertheless, instead of being stabilized by institutions which give them form, perpetuate them and install them, such individuals and ensembles are temporary or even occasional. What is preserved from one technical operation to the next is the elements, that is, tools and some manufactured objects. The making of a boat is an operation that requires a real technical ensemble: flat ground near a water-course, and area that is sheltered but bright and, along with that, supports and props to keep up the boat during construction. Even though a dry dock may be a temporary technical ensemble, it still constitutes an ensemble. Furthermore, in our own day temporary technical ensembles of this sort are to be found, some of them, for example building sites, highly developed and quite complex. There are others that are temporary but much more durable, such as mines or oil fields.

Every technical ensemble does not necessarily have to have the stable form of a factory or workshop. Indeed, non-industrial civilizations differ from ours especially in that they have no technical individuals. That is true, if we agree that the material existence of technical individuals does not have to be stable and permanent. However, the function of technical individualization is taken over by human individuals. Because in an apprenticeship a man forms habits, gestures, and ways of doing things, which enable him to use the many and various tools demanded by the whole of an operation, his apprenticeship leads him to technical self-individualization. He becomes the associated milieu of different tools he uses. When he has mastered all the tools and knows when to change tools to carry on working or to use two tools at the same time, he is using his own body to insure the internal distribution and self-regulation of the job.[1] In some cases the integration of technical individuals into the ensemble is effected through the intermediary of an association of human individuals in teams of two or three or more. When such groups do not introduce

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[1]The nobility of artisan work is partly derived from this. Man is a depositary of technicality. His work is the sole expression of this technicality. His need to work is translation of this need of expression. To refuse to work, where one has a technical knowledge that can only be expressed in work because it can't be formulated in intellectual terms, would be to hide one's light under a bushel. On the other hand, the need for expression is no longer tied to work when technicality is immanent in knowledge that can be formulated in concrete terms that are independent of any kind of concrete actualization.

functional differentiation their direct goal is an increase in disposable energy or in speed of work. But when they have recourse to differentiation, then they provide a good illustration of the genesis of an ensemble that is composed of men employed more as technical individuals than as human individuals Drilling with bow and bit as it is described by classical authors is of this sort. So too is the mode of felling certain trees in our own day. And so also until quite recently, was the very common method of using a cross-cut saw to make planks and rafters, with two men working together in alternating rhythm. This explains why in certain cases human individuality can be used as a functional support for technical individuality. The existence of separate technical individualities is a fairly recent phenomenon, and in some ways it seems to be an imitation of man by the machine, the machine being the most general form of technical individuals. However, in reality there is very little similarity between the machine and man and, even when it so operates as to produce similar results, it hardly ever employs the techniques used by the individual man in his work. Indeed, the comparison between the two is most often very superficial. But if man feels frustration on account of the machine, it is because it replaces him as an individual in the working world; the machine takes the place of man the tool-bearer.

In the technical ensembles of industrial civilizations, positions in which many people have to work in tight synchronization are becoming rarer than in the past, a past that was characteristically artisanal. At the artisanal stage of production, as opposed to the stage of technical ensembles, it is quite common for certain kinds of work to require a grouping of human individuals who have complementary functions: two men are needed to shoe a horse, one to hold the hoof and the other to position the shoe and nail it on. In building, the mason had his helper, the hod-carrier. Threshing with flail required good perception of rhythmic structure to synchronize the alternating movements of the team-members. So, we can hardly say that only helpers were replaced by the machine. The very support for technical individualization has changed. This support used to be a human individual. Now it is a machine. The machine bears tools, and we can define the machine as that which both carries and directs its own tools. Man directs or controls the machine, the bearer of tools. He arranges the grouping of machines, but he does not bear tools. The machine does the main work, the work of both blacksmith and helper. Man separated from his role as technical individual, from what is the essential work of the artisan, can become either the organiser of the ensemble of technical individuals or a helper for technical individuals. He greases, cleans, picks up burrs and debris and, so, in many respects, plays the part of helper. He supplies the machine with elements, changing the driving belt, sharpening the drill or lathe. Thus he has one role beneath technical individuality and another above it. Servant and master, he guides the machine as technical individual by attending to the relationship of the machine to its elements and to the ensemble. He is the organiser of relationships between technical stages instead of being, as artisan, one of those technical stages himself. For this reason a technician is less part of his own professional speciality than an artisan.

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However, this in no way means that man is not capable of being a technical individual and of working in liaison with the machine. The liaison between man and machine is realized when man uses the machine to act upon the natural world. So, the machine is a vehicle for action and information in a three-way relationship involving man, the machine and the world, with the machine in between man and the world. In such a case, man retains traces of technicality, which are defined by his need for an apprenticeship. The machine, then, has a relay function, as movement-amplifier, but all the while it is man who is the centre of the complex technical individual made up of man and machine. In this case we might say that man is a machine-bearer and that the machine retains its role as tool-bearer. Therefore, the relationship is to some extent comparable to that of the machine tool, where we understand machine-tool to mean one without self-regulation. Man is always the centre of the associated milieu in this relationship. The machine-tool is something lacking autonomous internal control and needing man to make it work. Here man intervenes as living being. Using his own sense of self-regulation he gives the machine self-regulation, without necessarily formulating this consciously. For example, a man lets an over-heating car engine sit until it has cooled down. Once it is cold he starts it and gradually speeds it up, without revving it too much at the beginning. These actions of his are technically proper and they have their parallels in regulations that are necessary for life, but they are just done, rather than thought out, by the driver. Actions of this kind are all the more applicable to the technical object the nearer it is to the status of technical being embodying homeostatic regulations in its functioning. Indeed, a technical object that has become concrete has a system which reduces the process of self-destruction to a minimum because homeostatic regulations are exerted to the best possible extent. A good example is the diesel engine, which requires a definite temperature to function and a rotation system within a narrow maximum and minimum range, whereas the petrol engine, being less concrete, has greater flexibility. Likewise, an electronic tube will not work at any random temperature or with an undetermined anode voltage. In power tubes, in particular, too low a cathode temperature causes the electric field to capture electron-emissive oxyde particles; hence the necessity of a gradual starting procedure, with, first, the warming of the cathodes and, then, the charging of the anodes. If polarization circuits are automatic (fed by cathode current), they have to be subjected to increasing voltage by a gradual increase in anode power. Without this precaution, there would be a brief instant when there is cathode output before polarization has reached its normal level (the polarization produced by this output, and proportional to it, tends to limit the output): cathode output would exceed the maximum admissable because it is not limited by this negative reaction.

To put it very generally, the precautions which man takes for the conservation of the technical object have the goal of maintaining and directing its functioning in conditions which render it non-self-destructive; that is, in conditions in which it subjects itself to a negative stabilizing reaction. Beyond certain limits, the reactions become positive and, consequently, destructive. This is the case where an over-heating engine, becoming too hot, begins to seize and, becoming still hotter because of the seizing, deteriorates irreversibly. Likewise, an electronic tube whose anode becomes red-hot loses its asymmetric conductivity, particularly in its function as rectifier and, as a result, enters a phase of positive reaction. The fact of allowing it cool off early enough allows for the recovery of normal functioning.

Thus, man can act as a substitute for the technical individual, and can join elements to ensembles in a era when the construction of technical individuals is not possible.

In reflecting on the consequences of technical development in relation to the evolution of human societies, we must take into account, first and foremost, the process of the individualization of technical objects. Human individuality becomes more and more detached from its technical function because of the construction of technical individuals. The functions that remain for man to perform are higher and lower in kind than the role of tool bearer, tending towards a relationship with elements and towards a relationship with ensembles. Now since, once upon a time, the individuality of man was precisely what had to be used in technical work and man had to be technicized because the machine could not be, there arose the habit of allotting, one sole function to each human individual in the world of work. This sort of functional monism was perfectly useful and necessary when man became a technical individual. But today it creates malaise because man still tries to be a technical individual but has no fixed place in relation to the machine. He becomes either servant of the machine[redacted] or organizer of the technical ensemble. Now, in order that the human function be meaningful, it is absolutely necessary that each man employed at a technical task should acquaint himself with every conceivable aspect of the machine, should arrive at some sort of understanding of it, and should pay attention as much to its elements as to its integration into the functional ensemble. For it is a mistake to create a hierarchical distinction between the care to be given to elements and the care due to ensembles. Technicality is not the kind of reality that lends itself to hierarchical distinctions. It exists wholly in elements and is transductively propagated in the technical individual and in ensembles. By means of individuals, ensembles are made up of elements and elements emerge from them. The apparent preeminence of ensembles arises from the fact that in our day ensembles are granted the prerogatives of persons who are in positions of leadership. However, ensembles are not individuals. Likewise, elements are not valued highly because working with elements was the job of helpers and because the elements used by these helpers were not highly developed. Therefore, the basis for the malaise in the man-machine relationship is the fact that until our own time man played the technical role of the individual. Now that he is a technical being no longer, man is forced to learn a new function and to find for himself a position in the technical ensemble that is something other than the position of individual. The first thing he must do is to take on two non-individual functions, that of the element and that of the director of the ensemble. But in both these functions man is in conflict with his memories of himself. Man has played the role of technical individual to the extent that he looks on the machine-as-technical-individual as if it were a man and occupying the position of a man, whereas in actual fact it was man who provisionally took the place of the machine before real technical individuals could be made. In all judgments made on the subject of the machine, there is an implicit humanization of the machine which has this role-change as its deepest source. Man had so well learned to be a technical being that he goes to the extent of believing that once the technical being is concrete it wrongly begins to play the role of man. Ideas about slavery and freedom are too closely bound to the old idea of man as technical object to be able to relate to the real problem of the relationship between man and machine. The technical object must be known in itself if the relationship between man and machine is to be steady and valid. Hence the need for a technical culture.