On the Mode of Existence of Technical Objects

By

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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 falls 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 <u>two contradictory attitudes</u> to technical objects. On the one hand, it treats them as pure and simple <u>assemblies of material</u> 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 <u>intentions</u>

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 organization 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 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 interrelationships 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 crystallized 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 ourselves 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. 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, thermodynamic 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 result of organization and information; it resembles life and cooperates with life in its opposition to disorder and to the levelling 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 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 hic et nunc, 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

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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.

not any particular engine in time and space; it is the fact that there is a sequence, a continuity, which extends from the first, given 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 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 fins specially developed in the valve region which are subject to intense changes in heat and high pressures. In early engines, the cooling fins are as it were extraneously added on to cylinder and cylinder-head which, in theory, are geometrically cylindrical: they fulfill a single function only, that of cooling. In recent engines, these fins have an added function of a mechanical kind, as reinforcing ribs 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 fins 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 fins 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 fins 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 fin-rib improves cooling not only by increasing the heat-change surface (this is the very function of the gill qua 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 fins while the vehicle is running. In that case, the maker can be obliged to settle for a mixed and imperfect design: if the fin-ribs are arranged for the best cooling possible, they should have to be heavier and more rigid than if they were mere fins. 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 fins which 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 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 handcraft. 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 made 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 convection 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 alternator and 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 causality.

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: <u>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</u>[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 control 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 assembly 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 control grid and the anode. Now, this adjunction does more than provide the advantage afforded by an electric screen. The screen cannot merely fulfill 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 its electrostatic function it has to fulfill 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 control 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 phenomenon of secondary emission of electrons by the anode proved awkward in that it tended to send back to the screen all of the electrons coining from the cathode and bypassing the control 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 control 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 control 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 control grid, there is a great reduction of the phenomenon of secondary 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 applied 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 control 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 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 is 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 thermo-electrons. 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 causalities 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 <u>function</u> by <u>function</u> but <u>synergy</u> by <u>synergy</u>. 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 concrete, 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 fulfill 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 attenuated 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 is 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 causality, 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 hydraulic press are all technical objects in which such phenomena such 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, Newcommen'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. <u>The Rhythm of Technical Progress; Continuous and Minor Improvement and Discontinuous and Major Improvement</u>

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 concretization 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-focusing 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 electronic characteristics.

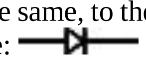
There are two kinds of improvements, then: those which modify the division of functions, increasing in an essential manner the synergy of functioning, and those which without modifying the division in question diminish the harmful effects of residual oppositions. To this order of minor improvement belong: 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 integrated 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 analyzed, 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 essential 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 uncoordinated 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 thermoelectronic 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 relation 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 electrid 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 from the 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, the hot electrode. The diode is a vacuum tube in which there is a hot electrode and a cold electrode between which an electric field is created. Here we surely have an absolute beginning; it is to be found in the condition of irreversibility of the electrodes and the phenomenon of the transport of electric charges across the vacuum; here we have the creation of a technical essence. 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 crystallized 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 (See Appendix), 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 type of diode used and which leaves complete freedom to the builder. But the pure technical diagram/model 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, fulfill 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 it possesses 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 admissible 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 carburetion. In an engine with preliminary combustion, carburetion can take place at any time before the introduction of the fuel mixture into the cylinder. In a diesel engine carburetion must take place after the introduction and compression of pure air, which is free of carbureting 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 (carburetion) 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 anoraic; 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 study 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 behavior observed by a spectator are not objects of scientific study.

It would not even be right to found a separate science for the study 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 study 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 organization, 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 inter-scientific 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 there from. 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 concretization.