CHAPTER ONE

GENESIS OF THE TECHNICAL OBJECT: THE PROCESS OF CONCRETIZATION

I. – The abstract technical object and the concrete technical object

Although the technical object is subject to genesis, it is difficult to define the gene- 21 sis of each technical object, since the individuality of technical objects is modified throughout the course of this genesis; technical objects are not easily defined by attribution to a technical kind; it is easy to summarily distinguish kinds according to practical usage, as long as one accepts grasping the technical object according to its practical end; however, this is an illusory specificity, because no fixed structure corresponds to a definite usage. The same result may be obtained from very different functionalities and structures: a steam engine, a gasoline engine, a turbine, and an engine powered by springs or weights are all equally engines, but there is a more genuine analogy between a spring engine and a bow or a cross-bow than between the spring engine and a steam engine; the engine of a pendulum clock is analogous to a winch, while an electric clock is analogous to a door bell or a buzzer. Usage unites these heterogeneous structures and operations under the banner of genera 22 and species that draw their signification from the relation between this functioning and another functioning, which is that of the human being involved in the action. That to which one thereby gives a single name — for instance the engine — can thus be multiple in one instance and may vary in time by changing its individuality.

However, instead of starting out with the individuality of the technical object, or even with its specificity, which is very unstable, it is preferable to reverse the problem, if we want to try to define the laws of its genesis in light of its individuality or specificity: one can define the individuality and specificity of the technical object on the basis of the criteria of its genesis: the individual technical object is not this or that thing, given *hic et nunc*, but that of which there is genesis.[1] The unity of the technical object, its individuality, and its specificity are the characteristics 23 of consistency and convergence in its genesis. The genesis of the technical object partakes in its being. The technical object is that which is not anterior to its coming-into-being, but is present at each stage of its coming-into-being; the technical object in its oneness is a unit of coming-into-being. The gasoline engine is not this or that engine given in time and space, but the fact that there is a succession, a continuity that runs through the first engines to those we currently know and which are still evolving. As such, as in a phylogenetic lineage, a definite stage of evolution contains dynamic structures and schemas within itself that partake in the principal stages of an evolution of forms. The technical being evolves through convergence and self-adaptation; it unifies itself internally according to a principle of inner resonance. Today's automobile engine is the descendent of the engine from 1910 not simply because the engine of 1910 was built by our ancestors. Nor is today's automobile engine its descendant simply because it has a greater degree of perfection in relation to use; in fact, for some uses the engine from 1910 remains superior to an engine from 1956. For instance, it can tolerate extensive heating without galling or rod bearing failure, having been built with more flexibility and without fragile alloys such as Babbitt metal; it is more autonomous, due to its having a magnetic ignition. Old engines function reliably on fishing boats after having been taken from a disused automobile. It is through internal examination of the regimes of causality and forms, insofar as they are adapted to these regimes of causality, that the contemporary automobile engine is defined as posterior to the engine from 1910. In a contemporary engine each important item is so well connected to the others via reciprocal exchanges of energy that it cannot be anything other than what it is. The shape of the combustion chamber, the shape and size of the valves,

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[1] According to determinate modalities that distinguish the genesis of the technical object from that of other types of objects: the aesthetic object, the living being. These specific modalities of genesis must be distinguished from a static specificity that one could establish after genesis by considering the characteristics of diverse types of objects; the point of using a genetic method is precisely to avoid using classification as a way of thinking that occurs after genesis only to distribute the totality of objects into genera and species suitable for discourse. The technical being retains the essence of its past evolution in the form of its technicity. According to the approach we shall call analectic, the technical being, as bearer of this technicity, can be the object of adequate knowledge only if the latter grasps the temporal sense of its evolution; this adequate knowledge is a culture of technics, distinct from technical knowledge, which is limited to the actuality of isolated schemas of operation. Considering that the relations that exist between one technical object and another at the level of technicity are horizontal as well as vertical, any form of knowledge that procedes by genera and species becomes inadequate: we will attempt to point out the way in which the relation between technical objects is transductive.

and the shape of the piston all belong to the same system within which a multitude of reciprocal causalities exist. To such a shape of these elements corresponds a certain compression ratio, which in turn requires a determinate ignition timing; the shape of the cylinder head, as well as the metal it is made of, produce a certain 24 temperature in the spark plug electrodes in relation to all the other elements of the cycle; this temperature in turn causes a reaction leading to the characteristics of ignition and hence to the entire cycle. One could say that the contemporary engine is a concrete engine, whereas the old engine is an abstract engine. In the old engine each element intervenes at a certain moment in the cycle, and then is expected no longer to act upon the other elements; the pieces of the engine are like people who work together, each in their own turn, but who do not know one another.

Moreover, this is precisely how the functioning of thermal engines is explained to students in the classroom, each piece being isolated from the others like the lines that represent it on the blackboard in geometric space, *partes extra partes.* The old engine is a logical assemblage of elements defined by their complete and unique function. Each element can accomplish its own function best if it is, like a perfectly completed instrument, oriented entirely to accomplishing this function. A permanent exchange of energy between two elements appears as if it were an imperfection, unless this exchange itself belongs to the theoretical operation; furthermore there is a primitive form of the technical object, *the abstract form*, in which each theoretical and material unit is treated as an absolute, and is completed according to an intrinsic perfection that requires, in order for it to function, that it be constituted as a closed system; integration into an ensemble in this case raises a series of so-called technical problems that must be resolved and which are in fact problems of compatibility between already given ensembles.

These already given ensembles need to be maintained and preserved despite their reciprocal influences. What appears then are particular structures that one can call, for each constitutive unit, defense structures: the cylinder head of the thermal combustion engine bristles with cooling fins that are particularly well developed in the region of the valves, which is subject to intense thermal exchanges and high pressure. In the first engines these cooling fins are as if added from the outside to 25 the theoretical cylinder and cylinder head, which are geometrically cylindrical; they serve only one function, that of cooling. In more recent engines, these cooling fins also play a mechanical role, as ribs that resist the deformation of the cylinder head under the pressure of the gasses; in these conditions one can no longer distinguish the volumetric unit (cylinder, cylinder head) from the thermal dissipation unit; if, in an engine that uses ambient air for cooling, one were to remove the cylinder head's fins by sawing or grinding, then the volumetric unit constituted by the cylinder head alone would no longer be viable, even as a volumetric unit: it would be deformed under the gaseous pressure; the volumetric and mechanical unit has become coextensive with the unit of thermal dissipation because the structure of the ensemble is bivalent: the fins constitute a cooling surface of thermal exchanges with the stream of external air; these same fins, insofar as they are a part of the cylinder head, limit the size of the combustion chamber through their un-deformable contour, using less metal than would be required by a shell without ribs; the development of this unique structure is not a compromise, but a concomitance and a convergence: a ribbed cylinder head can afford to be thinner than a smooth cylinder head with the same rigidity; a thin cylinder head, in turn, allows for more efficient thermal exchanges than a thick cylinder head would allow; the bivalent fin-rib structure improves the cooling not only by increasing the thermal exchange area (which is what characterizes the fin as a fin), but also by permitting a thinning of the cylinder head (which is what characterizes the fin as ribbing).

26 The technical problem is thus one of the convergence of functions into a structural unit, rather than one of seeking a compromise between conflicting requirements. If, in the case just considered, a conflict subsists between two aspects of a single structure, then this is only because the position of the ribbing that would correspond to maximum rigidity is not necessarily the same as that which corresponds best to their fastest cooling by way of air flowing between the fins when the vehicle is running. In this case the builder might have to retain a mixed, incomplete aspect: the fin-ribbing, if positioned for optimal cooling, will have to be thicker and more rigid than if it were for ribbing alone. If, on the contrary, they are positioned perfectly to resolve the problem of obtaining rigidity, then their area is larger, in order to compensate the reduction of the thermal exchange that had been diminished because of the slowed airstream, via the development of a larger area; the very structure of the fins may in the end also be a compromise between two forms, requiring a greater development than if a single function were taken as the sole purpose of the structure. This divergence of functional directions is like a residue of abstraction within the technical object and it is the progressive reduction of this margin between the functions of plurivalent structures that defines the progress of a technical object; it is this convergence that specifies the technical object, because in any given epoch there is no infinite plurality of possible functional systems; there are far fewer technical species than there are usages to which technical objects are destined; human necessity is infinitely diversifiable, but the directions of convergence of technical species are finite in number.

The technical object thus exists as a specific type obtained at the end of a convergent series. This series goes from the abstract to the concrete mode: it tends toward a state which would turn the technical being into a system that is entirely coherent 27 within itself and entirely unified.

II. – Conditions of technical evolution

What are the *reasons* for this convergence that manifests itself in the evolution of technical structures? A certain number of extrinsic causes no doubt exist, in particular those which tend to produce the standardization of spare parts and organs. Nevertheless, these extrinsic causes are not more powerful than those that tend toward the multiplication of types, appropriated for an infinite variety of needs. If technical objects do evolve toward a small number of specific types then this is by virtue of an internal necessity and not as a consequence of economic influences or practical requirements; it is not the production-line that produces standardization, but rather intrinsic standardization that allows for the production-line to exist. An effort to discover the reason for the formation of specific types of technical objects within the transition from artisanal production to industrial production would mistake the consequence for its condition; the industrialization of production is rendered possible by the formation of stable types. Artisanal production corresponds to the primitive stage of the evolution of the technical object, i.e., to the abstract stage; industry corresponds to the concrete stage. The *made-to-measure* aspect one finds in the product of artisanal work is inessential; it is the result of this other, essential aspect of the abstract technical object: namely, that it is grounded in an analytical organization that always leaves the path open for new possibilities; these possibilities are the external manifestation of an internal contingency. In the confrontation between the coherence of technical work and the coherence of a system of the needs of utilization, it is the coherence of utilization that prevails, because the technical object that is made to measure is in fact an object without 28 intrinsic measure; its norms are derived from the outside: it has not yet realized its internal coherence; it is not a system of the necessary; it corresponds to an open system of requirements.

Conversely, during the industrial stage, the object achieves its coherence and it is the system of needs that is now less coherent than the system of the object; needs mold themselves onto the industrial technical object, which in turn acquires the power to shape a civilization. It is utilization that becomes an ensemble chiseled to the measures of the technical object. When individual fancy calls for a customized automobile, the manufacturer can do no more than take a serial engine, a serial chassis, and externally modify some aspects, adding decorative details or externally adjusted accessories to the automobile, which is really the essential technical object: what can be made to measure are inessential aspects, because they are contingent.

The type of relation that exists between these inessential aspects and the nature proper to the technical type is a negative one: the more the car is required to answer to a large number of user demands, the more its essential characteristics are encumbered with external servitude; the bodywork burdens itself with accessories, shapes no longer correspond to the structures facilitating the best air flow. The made-to-measure aspect is not only inessential, it goes against the essence of the technical being, it is like a dead weight imposed from the outside. The car's center of gravity rises, its mass increases.

It is not enough, however, to claim that the evolution of the technical object occurs via a passage from an analytic order to a synthetic order, conditioning the passage from artisanal production to industrial production: even if this evolution is necessary, it is not automatic and one ought to seek the causes of this evolving
29 movement. These causes essentially reside in the imperfection of the abstract technical object. Because of its analytic aspect, this object uses more material and requires more construction work; it is logically simpler, yet technically more complicated, because it is made up of a convergence of several complete systems. It is more fragile than the concrete technical object, because the relative isolation of each system that constitutes a functional sub-system threatens, in case of its malfunction, the preservation of the other systems. In an internal combustion engine the cooling process might thus be accomplished by an entirely autonomous sub-system; if this sub-system ceases to work, the engine might deteriorate; if, on the contrary, the cooling process is the effect resulting from the solidarity of the functioning of the whole, then the functioning itself implies cooling; in this sense, an air-cooled engine is more concrete than a water-cooled engine: thermal infrared radiation and convection are effects that cannot but take place; they are necessitated by its functioning; cooling by water is semi-concrete: if it were accomplished entirely by a thermosiphon,* it would be almost as concrete as cooling by air; but the use of a water pump, receiving energy from the engine via the transmission belt, increases the element of abstraction of this kind of cooling; one could say that cooling by water is concrete in terms of a safety system (the presence of water enables summary cooling for a few minutes when the transmission from engine to pump is deficient, thanks to the absorption of calorific

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* cf. glossary of technical terms. [TN]

energy through evaporation); in its normal functioning, however, it is an abstract system; moreover, an element of abstraction still subsists in the possibility of the cooling circuit lacking water. Ignition via an ignition coil and accumulator battery is, likewise, more abstract than ignition by magneto,* which is itself more abstract than ignition by the compression of air followed by fuel injection, such as those 30
used in diesel engines. One could say that in this sense an engine with a magnetic fly-wheel and which is air-cooled is more concrete than a typical car engine; each piece plays several roles here; it is not surprising that the scooter is the brain-child of an engineer specializing in aviation; while the automobile can afford to preserve remnants of abstraction (cooling by water, ignition by battery and coil), aviation is obliged to produce the most concrete technical objects, in order to increase safe functioning and diminish dead weight.

Thus properly speaking, there is a convergence of economic constraints (a diminished quantity of raw material, of work and of energy consumption during use) and technical requirements: the object cannot be self-destructive, it must maintain itself in a stable state of functioning for as long as possible. As far as these two types of cause — the economic and the properly technical — are concerned, it would appear that it is the latter that predominates in technical evolution; economic causes indeed exist in all domains; yet it is mostly within the domains where technical constraints prevail over economic constraints (aviation, military equipment) that become the most active sites for progress. Indeed, economic causes are not pure; they interfere with a diffuse network of motivations and preferences that attenuate or even reverse them (a taste for luxury, the user's desire for very apparent novelty, commercial propaganda), to such an extent that in domains where the technical object is known through social myths or fads in public opinion, rather than being appreciated in itself, certain tendencies toward complication come to light; some car manufacturers thus present the use of overabundant automatism in accessories or the systematic recourse to servo-mechanisms as an increase in 31
perfection, even where direct command does not in the least exceed the physical strength of the driver: some even go so far as to find a sales argument and proof of superiority in the suppression of direct means, as for instance that of the use of the crank as a back-up means of starting the engine, which in fact consists in making its operation more analytic in subordinating it to the use of available electric energy accumulated in batteries; technically this represents a complication, whereas the manufacturer presents this suppression as a simplification that would show how modern the car is, thereby making the unpleasant affective connotations of the stereotypical image of a car engine that is difficult to start a thing of the past.

A nuance of ridicule is thus projected onto other cars — those that preserve the crank — which are somehow out of date, discarded into the past through an artifice of presentation. The automobile, a technical object charged with psychic and social inferences, is not suitable for technical progress: the automobile's progress comes from neighboring domains, such as aviation, shipping, and transportation trucks.

The specific evolution of technical objects occurs neither in an absolutely continuous nor completely discontinuous manner; it is made up of stages that are defined by the fact that they produce successive systems of coherence; between stages marking a structural re-organization there can be an evolution of a continuous kind; this is due to the progressive perfection of details resulting from experience and use, and from the production of better adapted raw materials or auxiliary devices; for thirty years the automobile engine improved through the use of metals that were better adapted to the conditions of utilization, through the increase of the compression ratio as a result of research into fuels, and through the study of the particular form of cylinder heads and piston heads in relation to the phenomenon of detonation. * 32 The problem that consists in producing combustion while avoiding detonation can be resolved only through work of a scientific kind on the propagation of the explosive wave at the heart of a carburized mix, at different pressure levels, at different temperatures, with diverse volumes and starting from determinate ignition points. This effort, however, does not itself lead directly to applications: the experimental work remains to be accomplished and there is a technicity proper to this path toward progressive perfection. What is essential in the coming-into-being of this object are the structural reforms that facilitate the technical object's self-specification; even if the sciences were to stop progressing for a time, the progress of the technical object toward specificity would continue; the principle of this progress is effectively the manner in which the object causes and conditions itself in its functioning and in the reactions of its functioning on its utilization; the technical object, issued forth from the abstract work of the organization of sub-systems, is the theater of a certain number of reciprocal causal relations.

It is due to these relations, given certain limits of the conditions of utilization, that the object encounters obstacles within its own operation: *the play of limits, whose overcoming constitutes progress, resides in the incompatibilities that arise from the progressive saturation of the system of sub-ensembles;*[2] yet because of its very nature, this overcoming can occur only as a leap, as a modification of the internal distribution of functions, a rearrangement of their system; what was once an obstacle

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[2] They are the conditions of a system's individuation.

must become the means of realization. Such is the case regarding the evolution of the electronic tube, whose most common type is the radio lamp. What caused the structural reforms, whose end point is today's series of lamps, were the internal 33 obstacles preventing the proper functioning of the triode. One of the most problematic phenomena of the triode was the significant reciprocal capacitance within the system formed by the command grid and anode; this capacitance was in fact the capacitive coupling between two electrodes, and one could not notably increase the size of these electrodes without running the risk of initiating self-oscillation; this inevitable internal coupling had to be compensated for by way of an external assembly, in particular through neutrodyning, which was achieved by using an assembly of symmetrical lamps with anode-grid coupling.

In order to resolve the difficulty rather than avoid it, an electrostatic plate was inserted into the triode, between the command grid and the anode; this addition, however, adds more than just the advantage of an electric screen. The screen cannot exclusively accomplish the function of decoupling for which it was meant: placed inside the space between grid and anode, it intervenes with its differential potential (with respect to both grid and anode) as another grid with respect to the anode and as anode with respect to the grid. It needs to be brought to a potential superior to that of the grid and inferior to that of the anode; failing this condition, no electron passes through or else the electrons arrive at the screen rather than the anode. The screen thus acts upon the electrons in transit between the grid and the anode; it is itself both a grid and an anode; these two conjugated functions are not obtained intentionally; they impose themselves by themselves as a surplus that results from the systemic aspect of the technical object. In order to introduce the screen into the triode without disturbing its operation it must at once fulfill functions relating to the electrons in transit, as well as its electrostatic function. Considered as a simple electrostatic plate, it could be brought to any degree of voltage, provided this remains a direct current; but it would thereby upset the dynamic functioning of the triode. It necessarily becomes an accelerating grid for the flow of electrons 34 and also plays a positive role in the dynamic functioning: it notably increases internal resistance, and consequently the coefficient of amplification, when brought to a determinate level of voltage, defined by its exact position in the grid-anode space. The tetrode is then no longer simply a triode without electrostatic coupling between anode and command grid; the tetrode is an electronic tube with great gain, with which one can obtain an amplification of the order of 200 rather than an amplification of 30 to 50 as far as the triode is concerned.

However, this discovery also contained an inconvenience: what became problematic in the tetrode was a phenomenon of the secondary emission of electrons by the anode, which tended to bounce all the electrons coming from the cathode (the primary electrons) and which had already passed through the command grid back onto the screen in the opposite direction; Tellegen therefore introduced another screen between the first screen and the anode: once brought to a negative potential with respect to the anode and screen (generally the potential of the cathode or even more negative a potential) this wide-meshed grid no longer obstructs the arrival of accelerated electrons going from the cathode to the anode, but acts as a negatively polarized command grid and stops the return of secondary electrons going against the direction of the flow. The pentode is thus the outcome of the tetrode, in the sense that it contains a supplementary command grid with a fixed potential that completes the dynamic schema of functioning; the same effect of irreversibility, however, can be obtained by concentrating the flow of electrons into beams; if the bars of the accelerating screen-grid are placed in the electric shadow of the command grid wires, then the phenomenon of secondary emission is greatly reduced. Furthermore, the capacitance variation between cathode and screen-grid during functioning becomes very minor (0.2 pF instead of 1.8 pF), practically
35 preventing all frequency drift when the tube is used in a circuit that generates oscillations. Consequently, one could say that the tetrode's schema of functioning is not perfectly complete in itself, if one considers the screen merely as an electrostatic shield, that is, as a barrier that can be brought to any continuous voltage whatsoever; this definition, however, is too broad; the definition of the tetrode needs to include the multifunctionality of the screen into the electronic tube, which happens by reducing both the margin of indeterminacy of the continuous voltage to be applied to the screen (in order for it to be an accelerator) and that of its position in the grid-anode space; a first reduction consists in specifying that the continuous voltage will have to be an intermediary between the grid and the anode's voltage; one thus obtains a structure that is stable with respect to the acceleration of primary electrons, but which still remains indeterminate with respect to the transit of secondary electrons coming from the anode; this structure in turn is still too open, too abstract; it can be closed, so that it corresponds to a necessary and stable functioning, either via a supplementary structure — the suppressive grid or third grid — or through greater precision in the positioning of the screen-grid with respect to the other elements, which consists in aligning its wires with those of the command grid. It is worth noting that the addition of a third grid is equivalent to an increase in the degree of determinacy in the screen-grid's positioning: there

is a reversibility between the functional aspect of the determination of structures already existing by their reciprocal causality and the functional aspect of a supple- 36 mentary structure; closing down the system of the existing structures' reciprocal causality with increased determinacy is equivalent to adding a new structure specialized in accomplishing a determinate function. In the technical object there is a reversibility between function and structure; over-determination of the system of structures within the regime of their functioning makes the technical object more concrete by stabilizing its functioning without adding a new structure. A tetrode with targeted beams is equivalent to a pentode; it is even superior in its function as a power amplifier of acoustic frequencies, because of the lower degree of distortion it produces. The adjunction of a supplementary structure only constitutes genuine progress for the technical object if this structure incorporates itself concretely into the totality [*ensemble*] of dynamical schemas of functioning; for this reason we will say that the tetrode with targeted beams is more concrete than the pentode.

One must not confuse the increase of the concrete aspect of the technical object with the increase of the technical object's possibilities via a complication of its structure; for instance, a twin-grid lamp (which allows separate action on two 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, if need be,[3] be replaced by two independent triodes, whose cathodes and anodes would be connected externally while leaving the command grids independent. Conversely, the tetrode with targeted beams, is more evolved than Lee de Forest's triode, because it is the realization of a development, the refinement of a primitive schema of the flow of the electrons' modulation by fixed or variable electric fields.

The primitive triode has a greater degree of indeterminacy than modern electronic tubes, because the interactions between structural elements during the course of its functioning are not defined, except for a single one among them, namely the modulating function of the electric field created by the command 37 grid. The inconveniences that emerge of their own accord during functioning are *transformed into stable functions* by the successive specifications and closures of the system: the necessity for the grid's negative polarization to counteract heating and secondary emissions also contains the possibility of splitting the primitive grid's function into that of both a command grid and an accelerating grid; in a tube with an accelerating grid, the command grid's negative polarization can be reduced to a few volts, and in some cases one volt; the command grid becomes almost exclusively a command grid: its function is more efficient and the tube's gain increases.

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[3] Not entirely because each grid can modulate all the way, whereas with two lamps, it would be halfway.

The command grid is brought closer to the cathode; conversely, the second grid, the screen, moves farther away and establishes itself roughly at an equidistance between the anode and cathode. At the same time functioning becomes stricter; the dynamic system closes in on itself just as an axiomatic saturates. The first triode's gain could be regulated through the potentiometric variation of a cathode's heating voltage, acting on the density of electron flow; this possibility is barely available anymore in pentodes with a large gain, whose characteristics would be profoundly altered by an appreciable variation in the heating voltage supply.

It seems contradictory, of course, to affirm that the evolution of the technical object obeys both a process of differentiation (the triode's command grid is divided into three grids within the pentode) and a process of concretization, where each structural element fulfills several functions rather than a single one; but these two processes are in fact tied to each other; differentiation is possible because, in a conscious and calculated manner and in view of a necessary result, it enables the integration of correlative effects of the global functioning into the functioning of the ensemble, effects which had until then been more or less corrected by palliatives that were separate from the principle function.

38 The same type of evolution is noticeable in the passage from the Crookes tube to the Coolidge tube; the first is not only less efficient than the second; it is also less stable in its functioning, and more complex; the Crookes tube in fact uses the cathode-anode voltage to disassociate molecules or atoms of mono-atomic gases into positive ions and electrons, in order to then accelerate these electrons, conferring upon them an important amount of kinetic energy prior to their collision with the anticathode; conversely, in a Coolidge tube, the function of producing electrons is dissociated from that of the acceleration of already produced electrons; production is achieved through a thermoelectric effect (improperly called thermionic, probably because it replaces the production of electrons through ionization), and subsequently acceleration takes place; the functions are thus purified by their dissociation, and the corresponding structures are both more distinct and richer; the hot cathode of a Coolidge tube is richer from the point of view of its structure and its function than the cold cathode in a Crookes tube; and yet it is also a perfect cathode from the electrostatic point of view; all the more so since it has a rather narrow localization of the source of thermo-electrons, and the form of the cathode's surface surrounding the filament determines an electrostatic gradient that enables focalization of the electrons in a narrow beam falling onto the anode (a few square millimeters in current tubes); a Crookes tube, on the contrary, does not have a defined location narrow enough for the source of electrons that would

enable it to focalize a beam efficiently and thus obtain a source of X-rays nearing the ideal punctuality.

Moreover, the presence of ionizable gas in a Crookes tube not only had the inconvenience of being unstable (the hardening of the tube from a fixation of molecules on the electrodes; the necessity of contriving valves in order to reintroduce gas into the tube); the presence of the gas also brought with it another essential 39
inconvenience: the gas molecules became an obstacle for electrons that had already been produced and which were in the process of acceleration within the electrical field between the cathode and the anode; this inconvenience offers a typical example of a functional antagonism within the processes of an abstract technical object's functioning: the very gas that is necessary to produce the electrons that are to be accelerated becomes an obstacle to their acceleration. This antagonism disappears with the Coolidge tube, which is a deep vacuum tube. It disappears because the groups of synergetic functions are allocated to specific structures; each structure attains a greater functional wealth from this redistribution as well as a more perfect structural precision; this is the case for the cathode, which, rather than being a simple spherical cap or hemisphere made of any kind of metal, becomes an ensemble consisting of a parabolic bowl at the heart of which there is a filament producing thermo-electrons; the anode, which in the Crookes tube occupied an indifferent position with respect to the cathode, converges geometrically with the previous anticathode; the new anode-anticathode plays the two synergetic roles: that of the production of a potential difference with respect to the cathode (the role of the anode) and that of the obstacle against which the electrons, accelerated by differential potential, collide, thus transforming their kinetic energy into luminous energy of a very short wavelength.

These two functions are synergetic because it is only after having sustained the entirety of the potential drop of the electric field that the electrons acquire maximum kinetic energy; it is thus both at this moment and in this location that it becomes possible to extract the greatest electromagnetic energy by stopping them abruptly. The new anode-cathode finally plays a role in the evacuation of heat produced (as a result of the poor efficiency of the transformation of the electron's 40
kinetic energy into electromagnetic energy, roughly 1%) and this new function is fulfilled in perfect accord with the two previous ones: a plate of hard-to-fuse metal, such as tungsten, is embedded into the bevel-sawed solid copper bar that forms the anode-cathode at the point of impact of the electron beam; the heat that develops on this plate is conducted outside the tube via the copper bar, which extends to the outside as cooling fins.

There is a synergy between the three functions, as the electric characteristics of the highly conductive copper bar goes hand in hand with the thermal characteristics of this same bar as a heat conductor; furthermore, the beveled section of the copper bar satisfies the function of a target-obstacle (anticathode), the acceleration of electrons (anode) and the evacuation of produced heat. One could say that, under these conditions, the Coolidge tube is a Crookes tube that is both simplified and concretized, in which each structure fulfills a greater but synergetic number of functions. The imperfection of the Crookes tube, its abstract and artisanal aspect, requiring frequent touch-ups in its functioning, came from the antagonism of functions fulfilled by the rarefied gas; it is this gas which is eliminated in the Coolidge tube. The fuzzy, indefinite structure corresponding to the ionization is entirely replaced by the new thermoelectric aspect of the cathode, which is perfectly clear and quantitatively adjustable.

These two examples tend to show that differentiation goes in the same direction as the condensation of multiple functions within the same structure, because the differentiation of structures within a system of reciprocal causalities allows one to suppress side-effects that were hitherto obstacles (by integrating them into the functioning). The specialization of each structure is a specialization of a synthetic 41 positive functional unit, freed from undesired side-effects that affect functioning; the technical object progresses by way of an internal redistribution of functions into compatible units, replacing the contingency or antagonism of the primitive distribution; specialization does not occur *function after function*, but *synergy after synergy*; it is the synergetic group of functions and not the unique function that constitutes the true sub-system in the technical object. It is because of this search for synergies that the technical object's concretization can translate into an element of simplification; the concrete technical object is one that is no longer in conflict with itself, one in which no side-effect is detrimental to the functioning of the ensemble or left out of this functioning. In this manner and for this reason a function can be fulfilled by several synergistically associated structures in the technical object that has become concrete, whereas in the primitive and abstract technical object each structure is charged with the accomplishment of a definite function, and generally only one. The essence of the technical object's concretization is the organization of functional sub-ensembles within the total functioning; on the basis of this principle one can understand in what sense the redistribution of functions occurs in the network of different structures, both in the abstract technical object and in the concrete technical object: each structure fulfills several functions; but in the abstract technical object, it only fulfills one essential and positive function, integrated into the functioning of the ensemble; in the concrete technical object, all the functions fulfilled by the structure are positive, essential, and integrated into the functioning of the whole; the marginal consequences of the functioning, eliminated or attenuated in the abstract technical object by corrective measures, become stages or positive aspects in the concrete object; the schema of functioning incorporates marginal aspects; consequences that were irrelevant or harmful become chain-links in its functioning.

This progress presupposes that the engineer consciously endows each structure 42 with characteristics that correspond to all the components of its functioning, as if there were no difference between the artificial object and a physical system studied from the point of view of all knowable aspects of exchanges of energy, as well as physical and chemical transformations; each piece, in the concrete object, is no longer simply that which essentially corresponds to the accomplishment of a function desired by the builder, but part of a system where a multitude of forces act and produce effects that are independent of the fabricating intention. The concrete technical object is a physico-chemical system in which reciprocal actions take place according to all the laws of the sciences. The objective of the technical intention can attain perfection in the construction of an object only if it becomes identical to universal scientific knowledge. It should be emphasized that this latter knowledge must indeed be universal, because the fact that the technical object belongs to the class of fabricated objects, answering to this particular human need, does not in turn limit and in no way defines the type of physico-chemical actions that can occur in this object or between this object and the outside world. The difference between the technical object and the physico-chemical system studied as an object only resides within the imperfection of the sciences; the scientific knowledge that serves as a guide to predicting the universality of reciprocal actions exerted within the technical system is still affected by a certain imperfection; it doesn't allow for an absolute prediction with rigorous precision of all effects; this is why a certain distance remains between the system of technical intentions corresponding to a defined objective and the scientific system of knowledge of causal interactions that realize this objective; the technical object is never fully known; for this very reason, it is never completely concrete, unless it happens through a rare chance occur- 43 rence. The ultimate allocation of functions to structures and the exact calculation of structures could only be accomplished if the scientific knowledge of all phenomena likely to exist in the technical object were completely acquired; since this is not the case, a certain difference subsists between the technical scheme of the object (containing the representation of a human objective) and the scientific picture of phenomena for which it is the base (containing only schemas of reciprocal or recurrent efficient causality).

The concretization of technical objects is conditioned by way of narrowing the interval that separates the sciences and technology; the primitive artisanal phase is characterized by a weak correlation between the sciences and technology, whereas the industrial phase is characterized by a strong correlation. The construction of a determinate technical object can only become industrial when this object has become concrete, which means that it is known in an almost identical manner according to the intention of construction and according to the scientific view. This explains the fact that certain objects could be manufactured in an industrial manner well before others, a winch, a hoist, snatch blocks, and a hydraulic press are technical objects in which, for the most part, the phenomena of friction, electrical charging, electrodynamic induction, thermal and chemical exchanges can be neglected without leading to the destruction or malfunction of the object; rational classical mechanics are sufficient for a scientific knowledge of the principal phenomena that characterize the functioning of these objects we call simple machines: however, it would have been impossible to industrially manufacture a centrifugal gas pump or a thermal engine in the seventeenth century. The first industrially produced thermal engine, which was the Newcomen atmospheric engine, simply used the process of depression, because the phenomenon of the condensation of steam 44 under the influence of cooling was scientifically known. Electrostatic machines also remained artisanal nearly to the present day, because the phenomena of the production and transport of charges via dielectrics and then flowing of charges via the Corona effect, which had been qualitatively known since at least the eighteenth century, had not yet been subjected to rigorous scientific study; after the Wimshurst machine, even the Van de Graaff generator retained something artisanal, despite its large size and greater power.

III. – The rhythm of technical progress; continuous and minor improvements; discontinuous and major improvements

It is thus essentially the discovery of functional synergies that characterizes progress in the development of the technical object. It is appropriate to ask, then, whether this discovery takes place all at once or in a continuous manner. In terms of the reorganization of structures affecting functioning, it happens abruptly, but can contain several successive stages; the Coolidge tube, for instance, could not have

been conceived of before Fleming's discovery of the production of electrons by a heated metal; and yet Coolidge's static anode-anticathode tube is not necessarily the last version of a tube that produces X-rays or gamma rays. It can be improved and appropriated for more specific uses. An important refinement, for instance, enabling the acquisition of a source of X-rays closer to the ideal geometric point, consisted in employing a solid anode plate, mounted on an axis within the tube: this plate can be set in motion by a magnetic field created by an inductor placed outside the tube and in relation to which the plate is a rotor containing an armature; the region of impact of electrons becomes a circular line close to the edge 45
of the copper plate, and thus offers ample possibilities for thermal dissipation; however, the place where impact takes place is fixed, in a static and geometric manner, with respect to the cathode and the tube: the beam of X-rays thus comes from a geometrically fixed source, even though the anticathode rotates at high speed within this fixed point. Tubes with a rotating anode allow for an increase in power without increasing the size of the region of impact, or for a reduction in the size of the region of impact without diminishing the power; yet this rotating anode fulfills the functions of acceleration and absorption of electrons as perfectly as a fixed anode; it better fulfills the function of the evacuation of heat, which allows for an improvement of optical characteristics of the tube for a determinate degree of power.

Should one therefore consider the invention of the rotating anode to be a structural concretization of the Coolidge tube? — No, because it mostly plays the role of diminishing an inconvenience that couldn't be converted into a positive effect of the overall functioning [*fonctionnement d'ensemble*]. The inconvenience of the Coolidge tube, the residual aspect of antagonism that subsists in its functioning, is the poor yield of its conversion of kinetic energy into electromagnetic radiation; this poor yield probably does not constitute a direct antagonism between functions, but it does practically convert into a real antagonism; if the tungsten plate and the copper bar's melting point were infinitely high, then one could achieve the concentration of a very fine, powerful beam of very rapid electrons; but as the melting temperature for tungsten is in fact attained very quickly, one is limited by this poor yield producing a large quantity of heat, and one must resign oneself to sacrificing either the concentration of the beam, the density of electron flow, or the speed of electrons, which means sacrificing the punctuality of the X-rays' source, the quantity of radiated electromagnetic energy or the penetration of produced X-rays. If it were possible to discover a way of increasing the yield of energy trans- 46
formation that takes place on the anticathode piece, all the characteristics of the

Coolidge tube would be improved, thereby removing or diminishing the greatest antagonisms that subsist in this way of functioning. (A much weaker antagonism consists in the fact that the beam cannot be rigorously concentrated, because of the mutual repulsion of electrons, since they are affected by an electric charge with the same sign; this could be compensated for by way of devices aimed at a concentration comparable to those of either the cathode-ray oscilloscopes, or the electrostatic or electromagnetic lenses of electronic microscopes.) The rotating anode allows for a reduction of the consequences of the antagonism between precision and power, between optical and electronic characteristics.

There are thus two types of refinement: those which modify the distribution of functions, increasing the synergy of functioning in an essential way, and those which, without modifying this distribution, diminish the nocuous consequences of residual antagonisms; a more regular system of lubrication in the engine, the use of self-lubricating bearings, this order of minor improvements includes the use of more resistant metals or of more solid assemblages. The discovery of the high emission power of certain oxides or metals, such as thorium, has thus made it possible to build oxide cathodes that work at lower temperatures and absorb less heating energy for the same density of electron flux in the electronic tube. However important this refinement may be in practice, it nevertheless remains minor, and is suitable only for certain types of electronic tubes because of the fragility of the oxide coating. The rotating anode of Coolidge's high power tube is another minor 47 refinement; it provisionally replaces a major improvement which would consist in discovering high yield energy transformation, thus enabling a reduction of the power deployed to accelerate electrons to a few hundred watts, which in radiography tubes is currently on the order of several kilowatts.

In this sense, one can say that minor improvements obstruct major improvements, because they may mask the technical object's true imperfections by compensating for true antagonisms with an inessential artifice that is incompletely integrated into the functioning of the ensemble; the danger of abstraction recurs once again at the level of minor improvements; for instance, the Coolidge tube with a rotating anode is less concrete than a tube with static cooling facilitated by a copper bar and air cooling fins; if, for whatever reason, the rotation of the anode stops during the tube's functioning, the point receiving the concentrated beam of electrons in the anode will almost instantaneously melt and the whole tube would be damaged; this analytical aspect of functioning thus requires new kinds of adjustment, a safety system based on the conditioning of one functioning by means of another functioning; in the analyzed case, the generator of anodic voltage must be capable of functioning only if the anode is already rotating; power to the transformer that supplies the anode voltage is controlled by the passage of current to the inductor for the anode motor, through a relay; however, this subordination does not completely reduce the analytic distance introduced by the rotating anode device; current may pass into the inductor while the anode may not be effectively rotating, due, for instance, to a weakening of its axis; the transmitter may also stay switched on even if the inductor is not live.

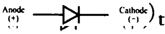
An extreme complication and refinement of ancillary safety or compensation systems can only tend toward an equivalence with the concrete technical object without attaining or even preparing for it, because the path chosen is not that of concretization. The path of minor improvements is one of detours, which may be 48 useful in some cases for practical use, but they hardly make the technical object evolve. By dissimulating the true schematic essence of each technical object behind a pile of complex palliatives, minor improvements entertain a false consciousness of a continuous progress of technical objects, diminishing the value and feeling of urgency for essential transformations. For this reason, continuous minor improvements present no clear-cut frontier with respect to this false novelty that commerce demands in order to present a more recent object as being superior to older ones. Minor improvements can be so nonessential as to allow for the cyclical rhythm of fashionable forms to superimpose itself over the essential shapes of use objects.

Therefore, it is not enough to say that the technical object is that for which there is a specific genesis proceeding from the abstract to the concrete; the point has to be made that this genesis occurs because of essential, discontinuous improvements, as a result of which the internal schema of the technical object is modified in leaps rather than following a continuous line. This does not mean that the development of the technical object happens by chance and outside any assignable meaning; on the contrary, the minor improvements are, to a certain extent, those which occur by chance, overcharging the pure shapes of the essential technical object with their uncoordinated proliferation. The true stages of the technical object's improvement occur through mutations, but through mutations which are oriented: the Crookes tube contains the potential for the Coolidge tube, since the intention that organizes and stabilizes itself in the Coolidge tube by purifying itself, pre-existed in the Crookes tube, in a confused yet real state. A great many abandoned technical objects are unfinished inventions that remain as an open virtuality and could be taken up again, prolonged in another domain, according to their deep intention, 49 their technical essence.

IV. – Absolute origins of the technical lineage

As with any evolution, that of technical objects poses the problem of its absolute origins: what is the first term one can attribute to the birth of a specific technical reality? Before the pentode and tetrode there was Lee de Forest's triode; before Lee de Forest's triode there was the diode. But what was there before the diode? Is the diode an absolute origin? Not entirely; thermoelectric emission, of course, was unknown, but the phenomena of the transfer of charges in space via an electric field had been known for a long time: electrolysis had been known for a century, and the ionization of gases for several decades; thermionic emission is necessary for the diode as a technical schema, because the diode wouldn't be a diode if there were reversibility of the transfer of electric charges; this reversibility doesn't exist in normal conditions, because one of the electrodes is hot, and therefore emissive, and the other cold, and therefore non-emissive; what makes a diode essentially a diode, a two way valve, is the fact that the hot electrode can be either cathode or anode almost indifferently, whereas the cold electrode can only be an anode since it cannot emit electrons; it can only attract, if it is positive, but not emit, even if it is negative with respect to another electrode. If one applies external voltage to the electrodes, a current will flow as a result of the thermoelectronic effect if the cathode is negative with respect to the anode, whereas no current will flow if the
50 hot electrode is positive with respect to the cold electrode. It is this discovery of a condition of functional dissymmetry between the electrodes that constitutes the diode, and not, properly speaking, that of a transfer of electrical charges through a vacuum mediated by an electric field: experiments with ionization of monoatomic gases had already shown that free electrons can move in an electric field; but this phenomenon is reversible, not polarized; if the tube of purified gas is turned upside down, then the positive column and luminous rings change sides in relation to the tube, but remain on the same side in relation to the direction of current coming from the generator. The diode is made up of the association of this reversible phenomenon of the transfer of electric charges by a field and the condition of irreversibility created by the fact that the production of transferable electric charges is the production of a single kind of (only negative) electric charges 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. What we have here is indeed an *absolute beginning*, residing in the association of this condition of irreversibility of the electrodes and of this phenomenon of

transfer of electric charges through a vacuum: it is a *technical essence* that is created. The diode is an asymmetrical conductance.

Nevertheless one should note that this essence is larger than the definition of the Fleming valve; several other procedures have been discovered for the creation of asymmetrical conductance; the contact between galena and metal, between copper and copper oxide, between selenium and another metal, between germanium and a tungsten tip, and between crystallized silicon and a metal tip are asymmetrical conductances. In the end, a single photoelectric cell can be considered a diode, since the photoelectrons behave like thermoelectrons in the vacuum of a cell (in the case of a vacuum cell, and also in that of a gas cell, but the phenomenon is complicated 51
by the emission of secondary electrons in addition to the photoelectrons). Should the name *diode* then be reserved for the Fleming valve? Technically, the Fleming valve can be replaced in several applications, by germanium diodes (for low intensities with high frequencies) or by a selenium or cupric oxide rectifier, for applications with low frequency and high intensity. Usage, however, does not offer good criteria: one could also replace the Fleming valve with a rotating converter,* which is a technique whose essential schema is entirely different from that of the diode. As a matter of fact, the thermoelectric diode constitutes a definite genus, which has its own historical existence; beyond this genus there is a *pure schema of functioning* that is transposable to other structures, for instance that of imperfect or semi-conductors; the schema of functioning is the same to such an extent that one can indicate a diode on a theoretical schematization with a sign (asymmetrical conductance: ) that does not predetermine the type of diode employed, leaving a freedom of choice to the manufacturer. However, the pure technical schema defines a type of existence of the technical object, grasped in its ideal function, which is different from the reality of a historic type; historically, the Fleming diode is closer to Lee de Forest's triode than to a germanium rectifier, to cupric oxide, or selenium and iron, which are nonetheless signaled by the same schematic symbols and in some cases fulfill the same functions to the point of being substitutable for the Fleming diode. This is because the whole essence of the Fleming valve is not reducible to its aspect of asymmetrical conductance; it is also that which produces and transfers a flow of electrons that can be slowed down, accelerated or deviated, as well as dispersed or concentrated, repulsed or attracted; the technical object exists not only as a result of its functioning within external 52
devices (asymmetrical conductance), but through phenomena for which it is in itself the basis: this is where its *fecundity* comes from, a *non-saturation* giving it posterity.

The primitive technical object can be considered a non-saturated system: any ulterior improvements it receives intervene as progress of the system toward saturation; viewed from the outside, one could think that the technical object alters and changes its structure rather than improving itself. But one could say that the technical object evolves by generating a family: the primitive object is the ancestor of this family. Such evolution could be called a *natural technical evolution*. In this sense, the gas engine is an ancestor of the gasoline engine and the diesel engine; the Crookes tube is the ancestor of the Coolidge tube; the diode is the ancestor of the triode and other tubes with multiple electrodes.

At the origin of each of these series, there is a definite act of invention; the gas engine follows, in a sense, from the steam engine; the disposition of its cylinder, of its piston, of its system of transmission, of its distribution by valves and ports is analogous to that of the steam engine; but it comes about by way of the steam engine like the diode comes about by way of the discharge tube through ionization in gases: what was needed was also a new phenomenon, a schema that did not previously exist either in the steam engine, or in the gas discharge tube; in the steam engine both the boiler producing gas under pressure and the source of heat were external to the cylinder; in the gas engine, it is the cylinder itself that, as a combustion chamber, becomes both boiler and firebox: combustion takes place inside the cylinder, it is an internal combustion; in the gas discharge tube, electrodes were indifferent, as conductance remained symmetrical; the discovery of the thermoelectronic effect allows for the construction of a tube that is analogous to the gas discharge tube in which the electrons are polarized, and which in turn
53 renders conductance asymmetrical. The beginning of a lineage of technical objects is marked by this synthetic act of invention constitutive of a *technical essence*.

A technical essence can be recognized by the fact that it remains stable across the evolving lineage, and not only stable, but also productive of structures and functions through internal development and progressive saturation; this is how the technical essence of the internal combustion engine was able to become that of the diesel engine, through additional concretization of its functioning: in the previous carburized engine, the heating of the carburized mix in the cylinder at the moment of compression is nonessential or even detrimental, since it risks producing a detonation instead of producing a deflagration (combustion with a progressive explosive wave), which limits the admissible compression ratio for a given type of fuel; this heating through compression, conversely, becomes essential and positive in the diesel engine, since this is what produces the beginning of deflagration; this positive aspect of the role of compression is obtained through a greater

precision of the determination of the moment in which carburetion must intervene in the cycle: in the previous carburized engine, carburetion could take place at any indeterminate moment before the introduction of the carburized mix into the cylinder: in the diesel engine, carburetion must take place after the introduction and compression of pure air, free of fuel vapors, at the moment in which the piston passes the top dead-center, because this introduction provokes the beginning of deflagration (the beginning of the power stroke in the cycle) and cannot provoke it unless it takes place at the moment in which, at the end of compression, the air attains its highest temperature; the introduction of fuel into the air (carburetion) is thus far more charged with functional significance in the diesel engine than in the gasoline engine; it is being integrated into a more saturated, more rigorous system, which allows the manufacturer less freedom and the user less tolerance. The triode is also a system that is more saturated than the diode; in the diode, asymmetrical 54
conductance is limited only by thermoelectric emission: when the cathode-anode voltage is increased, internal current increases more and more for a given temperature of the cathode, but reaches a ceiling (saturation current), which corresponds to the fact that all electrons emitted by the cathode are captured by the anode. One can thus regulate the current traversing a diode only by varying anodic voltage; on the contrary, the triode is a system in which one can vary the current traversing the anode-cathode space in a continuous manner without varying the anode-cathode voltage; the primitive property (the variation of current in direct relation to the anode-cathode voltage) subsists, but is accompanied by a second possibility of variation, which is determined by the command grid voltage; the function of variation that primitively adhered to the anode's voltage, becomes an individualized, free and defined property, which adds an element to the system and consequently saturates it, since the regime of causalities now comprises an additional component; this saturation of the system through the segregation of functions becomes intensified throughout the course of the evolution of a technical object; in the pentode, the current that traverses the cathode-anode space becomes independent of the anode's voltage for values of the anode's voltage between a very low minimum and a high maximum, defined by the possibility of thermal dissipation; this aspect is stable enough to allow utilization of a pentode as a load resistor in relaxation oscillators* that have to produce linear saw-tooth waves for voltages with horizontal deviation in cathode-ray oscillographs; in this case, the screen voltage, command grid voltage, and the third (suppressor) grid remain fixed. Conversely, in the triode, for a given voltage in the command grid, the anodic current varies according to the anode's voltage: in this sense, the triode

55 is still comparable to a diode, whereas this is no longer the case for the pentode in a dynamic state; this difference results from the fact that in the triode, the anode still plays an ambivalent role as both an electrode that captures electrons (a dynamic role) and as an electrode that creates an electric field (a static role); conversely, in the tetrode or pentode, the maintenance of the electric field, which regulates the flow of electrons, is taken care of by the command grid, which plays the role of an electrostatic anode; the anode plate simply retains the role of capturing electrons; for this reason, the gain of the pentode can be much greater than that of the triode, because the function of maintaining the field of electrostatic acceleration is ensured without variation or weakening (since the screen has a fixed potential), even when the anodic voltage lessens as the current increases, because of insertion of a load resistor in the anodic circuit. One could say that both the tetrode and the pentode eliminate the antagonism that exists in the triode between the function of acceleration of electrons by the anode and the function of capturing the electric charges transported by the electrons, which are accelerated by the same anode, a function which entails a drop in anodic potential when a load resistor is introduced and diminishes the acceleration of electrons. From this point of view, the screen grid must be considered an electrostatic anode with fixed voltage.

One can therefore see that the tetrode and pentode are both the result of the saturation and synergetic concretization of the triode's primitive schema. The screen-grid concentrates within itself all of the functions relating to the electrostatic field, which correspond to the preservation of a fixed potential; the command grid and anode preserve only the functions relating to a variable potential, which they can thus fulfill to a greater extent (during functioning the anode of a pentode deployed as a voltage amplifier can be brought to potentials varying between 30 and 300 volts in a dynamical state); the command grid captures fewer electrons
56 than a triode, which enables one to treat its input impedance as very high: the command grid increasingly becomes a pure command grid no longer exposed to the continuous current created by the captivating of electrons; it is, more rigorously speaking, an electrostatic structure. One can thus consider the pentode and tetrode as direct descendants of the triode, since they realize the development of its internal technical schema by reducing incompatibilities via the redistribution of functions into synergetic subsystems. It is the latency and stability of the concrete schema of organizational invention throughout its successive developments that ground the unity and distinctiveness of a technological lineage.

Concretization gives the technical object an intermediate place between the natural object and scientific representation. The abstract technical object, in other words the primitive technical object, is far from constituting a natural system; it is the translation into matter of a set of notions and scientific principles that are deeply separate from one another, which are attached only through their consequences and converge for the purpose of the production of a desired effect. This primitive technical object is not a natural, physical system, it is the physical translation of an intellectual system. For this reason, it is an application or a bundle of applications; it comes after knowledge, and cannot teach anything; it cannot be examined inductively like a natural object, precisely because it is artificial.

On the contrary, the concrete technical object, which is to say the evolved technical object, comes closer to the mode of existence of natural objects, tending toward internal coherence, toward a closure of the system of causes and effects that 57 exert themselves in a circular fashion within its bounds, and it moreover incorporates a part of the natural world that intervenes as a condition of functioning, and is thus part of the system of causes and effects. As it evolves, this object loses its artificial character: the essential artificiality of an object resides in the fact that man must intervene to maintain the existence of this object by protecting it against the natural world, giving it a status of existence that stands apart. Artificiality is not a characteristic denoting the fabricated origin of the object in opposition to spontaneous production in nature: artificiality is that which is internal to man's artificializing action, whether this action intervenes on a natural object or on an entirely fabricated one; a flower, grown in a greenhouse, which yields only petals (a double flower) without being able to engender fruit, is the flower of an artificialized plant: man diverted the functions of this plant from their coherent fulfillment, to such an extent that it can no longer reproduce except through procedures such as grafting, requiring human intervention. Rendering a natural object artificial leads to the opposite results to that of technical concretization: the artificialized plant can only exist in a laboratory for plants, the greenhouse, with its complex system of thermal and hydraulic regulations. Its system of primitively coherent biological functions has opened up into functions that are independent of one another, and only become attached to one another through the gardener's care; its flowering has become a pure flowering, detached, anomic; the plant flowers until it is exhausted, without producing seeds. It loses its initial capacity of resistance against cold, drought, and sun; the regulations of the primitively natural object become the artificial regulations of the greenhouse. Artificialization is a process of abstraction within the artificialized object.

Conversely, technical concretization makes the primitively artificial object increasingly similar to a natural object.[4] This object needed a regulative external milieu in the beginning, the laboratory, workshop, or sometimes the factory; it
58 gradually increases its concretization, it becomes capable of doing without the artificial milieu, because its internal coherence increases, its functional systematicity closes as it organizes itself. The concretized object is comparable to the spontaneously produced object; the object frees itself from the originally associated laboratory and dynamically incorporates the laboratory into itself through the play of its functions; what enables the self-maintenance of the object's conditions of functioning is its relation to other technical and natural objects, and it is this relation that becomes regulative; this object is no longer isolated; it associates itself with other objects, or suffices unto itself, whereas at first it was isolated and heteronomous.

The consequences of this concretization are not only human and economical (allowing decentralization, for example), they are also intellectual: since the mode of existence of the concretized technical object is analogous to that of natural spontaneously produced objects, one can legitimately consider them as one would natural objects; in other words, one can submit them to inductive study. They are no longer mere applications of certain prior scientific principles. By existing, they prove the viability and stability of a certain structure that has the same status as a natural structure, even if it might be schematically different from all natural structures. The study of the functioning of concrete technical objects bears scientific value, since its objects are not deduced from a single principle; they are testimony to a certain mode of functioning and compatibility that exists in fact and has been built before having been planned: this compatibility was not contained in each of the separate scientific principles that served to build the object; it was discovered empirically; one can work backward from the acknowledgement of this compatibility to the separate sciences in order to pose the problem of the correlation of their principles and ground a science of correlations and transformations that would be a general technology or mechanology.

59 However, for this general technology to make sense, one must avoid the improper identification of the technical object with the natural object and more specifically with the living being. External analogies, or rather resemblances, must be rigorously banned: they have no signification and are only misleading. Dwelling on automata is dangerous because it risks limiting one to the study of external aspects and thereby to improper identifications. The only thing that counts is the exchange of energy and information within the technical object or between the

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[4] Variant: the object frees itself and becomes naturalized. — Ed.

technical object and its milieu; external behaviors as viewed by a spectator are not objects of scientific study. One needn't even found a separate science that would study the mechanisms of regulation and command in automata built to be automata: technology must deal with the universality of technical objects. In this sense, cybernetics is insufficient: it has the immense merit of being the first inductive study of technical objects, and of presenting itself as a study of the intermediate domain between the specialized sciences; but it has specialized its domain of investigation too narrowly, because it started from the study of a certain number of technical objects; it accepted as its point of departure that which technology must reject: a classification of technical objects according to criteria established according to genera and species. Automata are not a *species*; there are only technical objects, which in turn have a functional organization that results in various degrees of automatism.

What risks making the work of cybernetics partially inefficient as an inter-scientific study (which nevertheless is the objective Norbert Wiener attributes to his research) is the initial postulate concerning the identity between living beings and self-regulating technical objects. Yet the only thing we can say is that technical objects tend toward concretization, whereas natural objects, such as living beings, are concrete to begin with. One mustn't confuse the tendency toward concretization with the status of entirely concrete existence. To a certain extent, every 60
technical object has residual aspects of abstraction; one mustn't go right to the limit and speak of technical objects as if they were natural objects. Technical objects must be studied in their evolution in order to discern the process of concretization as a tendency; but one mustn't isolate the last product of technical evolution in order to declare it entirely concrete; it is more concrete than the preceding ones, yet it is still artificial. Instead of considering one class of technical beings, automata, one must follow the lines of concretization throughout a temporal evolution of technical objects; it is only by following this path that the rapprochement between the living being and the technical object makes any true sense, beyond any mythology. In the absence of any end-point thought out and realized by living human beings on Earth, physical causality could not, in the majority of cases, have produced a positive and efficient[5] concretization on its own, even though modulating structures exist in nature (relaxation oscillators, amplifiers) — wherever metastable states exist, and this is perhaps one of the aspects of the origins of life.

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[5] The end of this sentence is a correction intended for the 1958 manuscript. — Ed.