History and Technology, 1985, Vol. 2, pp. 115-132
0734-1512/85/0202-0115 $12.00/0

Printed in the United Kingdom

FOUNDATIONS AND METHODS

More (and enough) on technology!

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TO DISCUSS WORDS endlessly, it is said, was a favorite pastime of Byzantine theologians. It still is among French intellectuals, to judge by the two papers by Sebestik (1983) and Salomon (1984) recently published in this journal. These papers are interesting, but I believe that having read them, one is left largely as perplexed as before. J. Guillerme, who co-authored with Sebestik the classic paper published in *Thalès* (1966) on the same subject, recently declared that his collection of definitions of *technologia*, *technologie* or *technology*, now amounts to more than 600 items — with no clear conclusion in sight. If the present trend continues, I am afraid that Guillerme will soon have to add to his collection an increasing number of whole papers, not to mention books, with much the same disappointing results. With this in mind, I decided that it would not make much difference to add one item to that next collection of Guillerme's, provided it was short enough.

As far as concision is concerned, however, the winner is probably Combarnous (1984), who summarizes as follows the meanings of *technologie* in French (pp. 32, 33):

— "*technologie, étude de procédés techniques*"

— "*technologie, groupe de techniques*"

The first meaning, Combarnous says, "conforms with etymology and traditions". The second meaning was developed in France in the

1950s and 1960s, under the influence of the Anglo-American usage of *technology*. Although disapproved of by the Comité d'étude des termes techniques, this use of *technologie* as "un ensemble de moyens d'action" cannot, and probably should not, be expected to disappear soon.

Thus, in less than three pages, Combarnous is able to settle the matter simply, clearly and conclusively, in full agreement with the current French usage of today. So, one may ask — what is the problem?

There may well be some problem with the English usage, as is shown by Mumford's attempt to use the word *technics*. But Mumford himself found very few followers (Sebestik being among them). In any case the problem, if it is a problem, concerns English speakers only. Why should French authors care about it at all?

It is my opinion that there is no problem whatever, probably not in English, and certainly not in French. There is no problem, but there may well be a conflict. The aim of this paper is to expose this conflict.

* * *

There is indeed a third sense of *technologie* in French, ignored by Combarnous (perhaps intentionally), but increasingly used, or at least implied, over the last two decades. In that sense, *technologie* is the equivalent of *technique*, but with a scientific twist, that is to say *technique* in a scientific context, or the systematic use of scientific knowledge and methods in the technical field, in production, etc. I believe that the conflict mentioned above has much to do with this third sense of *technologie*, although how will become clear only later.

One of the first authors to have explicitly made use of this third sense may be the late M. Daumas (1965: XVI-XVII), who takes care to put the word *technologie* between quotation marks, however, and who cautiously writes:

> Nous nous en servirons ici pour désigner *un peu arbitrairement* une sorte de technique élevée, de technique savante, ou mieux la science de la technique. Sans aller plus avant dans la recherche d'une définition précise, le lecteur comprendra qu'il s'agit d'attirer l'attention sur ce domaine d'activité commun aux sciences et aux techniques, mais en même temps différent de chacune d'elles ... (My italics.)

Daumas was certainly too practical a man to spend much time discussing at length the possible drawbacks of a conveniently available word, and anyway, his explanations were clear enough for the purpose. On the other hand, he seems to have been well aware of the difficulties to be expected if his "definition" of *technologie* was too strictly adhered to. Indeed, he abstained from pushing the point further himself, except for hinting here and there that things are not simple — that, for example, the idea of a "technical revolution" contemporary with the so-called "industrial revolution" is largely a myth (1968: XVI), or that the interaction of science and *technique* is older than currently recognized (1968: XVIII; 1978: XXIV).

With hindsight, we can see clearly now that Daumas was right to have second thoughts on the matter. If we accept science as the criterion to distinguish *technologie* from *technique*, indeed, some pretty awkward questions are inevitable. And first, of course: where are we to draw the line? Is the steam engine *une technique* or *une technologie*? And the mill? And the screw? And the wheel? If *la technologie* is defined as scientific, does that mean that *la technique* is unscientific? And if so, what kind of reasoning is at work here? And by the way (horresco requirens), how are we to tell, in the field of material acts, what is scientific from what is not?

I do not believe it necessary to belabour the point further. Defining *la technologie* as *technique scientifique* can lead only to confusion. Above all, it is unnecessary. Combarnous, himself a seasoned engineer and teacher of technology, ignores this third sense of *technologie*, surely sparing himself a lot of trouble in the process. He is quite aware of the present-day *association des sciences et des techniques*, but he does not forget that this association is not simply a recent phenomenon, for science and technology have always been inextricably involved with each other:

> Le monde matériel, celui que la science s'efforce de connaître et sur lequel la technique s'applique à agir, est rigoureusement unique; nos divisions en domaines et en disciplines ne sont que des fractionnements de commodité (...)
>
> Les techniques et les sciences ont une origine historique commune. (...)
>
> Dans le période contemporaine, savants et techniciens observent les mêmes faits, connaissent les mêmes lois, utilisent les mêmes méthodes. (...) Les moyens d'observations et les instruments sont communs à toutes les sciences et à toutes les techniques ..." (Combarnous 1984: 81-82.)

So, if we follow Combarnous, the separation between scientists

and technicians, between science and *technique*, is, and always has been, artificial. One thing only distinguishes them: the scientist has to act in order to know, whereas the technician has to know in order to act. Their respective ends and means are in reverse order.

That is exactly my opinion too. Science has always used (and not infrequently invented) *techniques*, and always will. Yet it will never aim at something other than knowledge, or it will cease to be science. *Technique* has always used whatever knowledge could be found (including scientific knowledge, inasmuch as it was available and relevant). But it simply cannot aim at something other than the production of material goods and services, or it is not *technique* any more. To put it in a nutshell, *technique* will always be *technique*, whatever the amount of scientific knowledge and methods it makes use of. Attempting to separate *technique* from *technologie* on the basis of their scientific content, or context, can only confuse things. It is irrelevant and useless.

* * *

Salomon, however, tries to do just that: he defines *la technologie* as "the close association between scientific research and the industrial production of technical innovations" (p. 151). His scholarly paper contains a lot of valuable arguments explaining his position, but it also contains some very disturbing fallacies. So much so, in fact, that I cannot find it really convincing. It is not possible here to discuss Salomon's paper at any length. So, at the risk of appearing rather unfair, I shall limit myself to discussing one of its most conspicuous fallacies: it concerns the early history of the steam engine.

In his effort to show that "the scientific age of *technique* commenced with Edison" (p. 153), Salomon naturally tries to minimize the rôle of science before Edison, during what he calls the age of "paleotechnology". It comes as no surprise, then, that he repeats the old tale according to which "the steam engine was born and developed without recourse to science" (p. 149). Unfortunately for his demonstration, this tale is one of the most baseless legends in the history of technology.

Everyone knows or should know, indeed, that the first steam engines (including Watt's, notwithstanding the exception to a certain

degree of Savery's) were atmospheric engines. That is to say that in them, steam was not directly used to push the piston. Steam was used to provide a vacuum, so as to allow atmospheric pressure to push the piston. Atmospheric engines, in fact, worked as vacuum pumps — they were pumps in the first place. As such, they were directly derived from the experiments on the weight of air and the pressure of gases pioneered by Toricelli (1643) and von Guericke (1650s), to be so successfully developed by the like of Pascal, Boyle, Mariotte and Amontons, not forgetting Huygens and his one-time assistant Denis Papin. If all this is not science, and of the higher order, what is? Now, Amontons, Huygens and Papin designed or experimented with different designs of thermal engines. Savery's patent was issued in 1698, a mere fifty years after the first experiments by Toricelli and Guericke — which is not very long, even by modern standards. In fact, it is hard to find a more superb example of closely related developments in science and in technology than the early steam engine.

As for Watt, Salomon himself is forced to record several arguments against his main point. Watt, he concedes, "possessed *some* scientific knowledge which he never ceased to broaden." (My italics.) "The environment of the university shaped his aptitude for mechanics." And also, "he made the acquaintance of Joseph Black, to whom we owe the discovery of steam-generated heat ..." (p. 148). Indeed. As a matter of fact, Black discovered latent heat in 1764, and Watt got his idea of the condenser in May 1975, although his first engine was to be built only in 1776. What more superb example can you expect of an interaction between science and *technique*? Yet, we are immediately and inexplicably told that "one cannot conclude, however, that a very high level of scientific knowledge was necessary for his (Watt's) work" (p. 148).

I leave it to Salomon to say whether Watt's level of scientific knowledge was very high, high, medium, passable or insufficient. But the key to understand his (Salomon's) mode of thinking may be this: "In the contemporary sense of the word", he argues, "Watt was even less of a scientist in that the scientific knowledge necessary to resolve his technical problems did not exist." We have just seen what the second part of the sentence is worth; as for the first one, translated into ordinary English, it reads: "by modern standards, Watt knew far less physics than any student graduating from high school today". Granted, but irrelevant.

In fact, Watt plausibly knew as much physics as there was to know in his time. And from this scientific knowledge, he derived at least one of his most basic inventions, the condenser. Add to this Boulton's commercial expertise, and you get the three basic ingredients — science, *technique*, economy — that according to Salomon are not really to be found together before one full century later, that is before Edison's time.

But the combination of these three basic ingredients, under other names possibly — let us say knowledge, skills, and a sense of usefulness — is to be found not only one century before Salomon wants to find them, but throughout history. No successful innovation has ever been possible without them. Neither Edison, nor Watt, nor Archimedes, nor the men who found efficient uses for the wheel, fire, or chopping stones, can "appear as the symbolic beginning of the truly technological era". There is simply no more a "truly technological era" than there is a classless society, or any kind of future paradise repeatedly imagined by men in their foolish desire to put history under control at last. One wonders why Descartes and Comte are both quoted at length by Salomon, since neither made any contribution worth mentioning to technological thought. The point could be that both Comte and Descartes were prophets as well as scientists. Both claimed to have discovered the foundations of the "modern world", after millennia of groping in the dark by their unfortunate predecessors. Does Salomon claim anything else when he concludes, triumphantly, that "Menlo Park symbolizes the institutional framework in which the break between paleotechnology and the modern world was completed"?

"What are the differences between an abacus and a microcomputer, a candle's light and that of an electric bulb, a stone projectile and an atomic bomb?" asks Salomon at the beginning of his paper (p. 115). Those are exactly the kind of questions that make one wonder if they are to be taken seriously, or just as a rhetorical trick. In between a stone projectile and an atomic bomb, you can bet that a "break" will be found in the end — what else? To locate that "break" at Menlo Park or elsewhere, then, becomes a matter of taste. It is not a matter for serious discussion.[1]

* * *

So taking *technologie* as *technique scientifique* leads us nowhere. Let

us come back, then, to *technologie* as *étude de procédés techniques.* There seems to be no reason to think that this *technologie* according to Combarnous is really different from the "technological science" dealt with historically by Sebestik (1983). How is it, then, that Combarnous does not seem to harbour any uneasiness about the matter, whereas Sebestik concludes, with some apparent nostalgia, that:

> The historian may think that in the technology understood in this sense, there is nothing more than a chimerical project and that the unity of its subject is, as further development shows perhaps, illusory and artificial; he would, however, fail in his duty if he ignored the endeavour of men to understand themselves as nature transforming beings.

Much more than this short paper would be needed for a complete analysis of this discrepancy. The most that I can possibly do here is to present my hypothesis, and to give some clues to readers interested in getting more information, the first and most important of these clues being the paper by Sebestik just quoted, and the papers by Guillerme and Sebestik and by Morère published in the special number of *Thalès* (1966) already alluded to. It is assumed that readers are well acquainted with those works, and with the history of technology in general. From now on moreover, I will translate *technologie* as "technology" and *technique* as "technics", according to Mumford's and Sebestik's examples, in order to prevent an excess of italics.

So the question we are faced with is as follows: how is it that technology, considered quite simply as "a study of technics", is taken for granted by teachers like Combarnous and many others (like Géminard, Chabal *et al.*, etc), whereas it is considered by Sebestik and Salomon as a no-future pursuit?

Obviously, at least part of the answer must lie in the fact that both Sebestik and Salomon have in mind, not the whole of technology, but only the specific conception Beckmann had of it. Insofar as this Beckmannian conception of technology seems to have faded away after 1830 or 1840, it may not be unreasonable to argue that it really had no future. In my opinion, however, this conclusion is decidedly rash. How is it possible to be quite sure that some of Beckmann's basic ideas did not make their way, under one form or another, into the technological thought of later times? We know far too little, I think, to give this question a definitely negative answer. On the contrary, what little evidence I happen to have seems to me to point in

the opposite direction. People with such different backgrounds as Alfred Espinas or Charles Frémont seem to me to belong to Beckmann's tradition, although they most probably were not aware of it. Even today, definitions of technology by Géminard (1970: 4) or Chabal *et al.* (1973: 7) sound quite Beckmannian. But in addition, one can only declare Beckmann's idea of technology dead if one has first decided completely to ignore the human sciences. Studying ancient and exotic peoples' technics is an old tradition of history and anthropology — about as old as history and anthropology themselves.[2] And, at least in ethnology, this study has been called "technology" for a very long time. I can think of no sound reason why this "historical" or "cultural" technology, as it is sometimes called, should be disregarded. If it is not, then there is no escaping the conclusion that a good part at least of the Beckmannian idea of technology is alive (if not as healthy as one would wish). Ideas are notoriously difficult to kill: this one may well have been buried too soon.

Moreover, if Sebestik is right — and I very much think he is — when he describes Beckmannian technology as an "endeavour of men to understand themselves as nature-transforming beings", then it necessarily follows that either this endeavour must have a future after all, or none of the human sciences has. For if men cannot hope to understand themselves as nature-transforming beings, I cannot possibly imagine any way they could hope to understand themselves at all.

* * *

At this point, the reader is well entitled to ask for a clear statement of exactly what this writer's conception of technology is. The simplest way to do it, I believe, is to propose a few analogies, at the risk of exposing some inadequacies.

To summarize, then, my view is that technology is to technics about what linguistics is to language, biology to living beings, psychology to mental activity, epistemology to knowledge, etc. That is, technology is to technics what any science is to its object, which, of course, implies that technology is a science: its definite aim is to acquire knowledge on technics (i.e. on the technical activity of men), not to use or to develop technics, at least not primarily. This conception, *mutatis mutandis*, is quite equivalent to that of Beckmann, of Mauss and of a number of the latter's fellow ethnologists.

I am of course fully aware of the difficulties inherent in this conception. For otherwise, how could it possibly have been so steadily refused any real status in the scientific community? However, most of these difficulties are classical ones: they have been dealt with time and again (often unwittingly) by philosophers and historians from the time of Aristotle onwards, and possibly earlier. Dealing with those difficulties in any relevant way is self-evidently not possible within the limits of this paper. Suffice it to say that at any specific time in history, ideas on technics are closely related to ideas on nature, and on society: I can do no more than refer the reader to the general literature (for example: Espinas 1878 and 1897, Lenoble 1969, Elster 1983, etc.). For the present argument, two things can and must be stressed: first, that this conception of technology *can work*; and second that despite appearances, it agrees with the other serious conceptions of technology that have been developed historically.

Technology, considered as the science of technics, works: anybody who has practised it thoroughly enough knows it. This conviction cannot be transmitted by mere words, however. Personal experience acquired through research is a prerequisite. But I think it possible to hint at what that conviction may be, by coming back to some of our analogies. To linguistics, for example. For millennia, people were unable to conceive that a study of language could be aimed at anything other than direct, practical use: that is, grammar and rhetoric. With the discovery of Sanskrit in the 18th century, the idea emerged that languages changed with time, and that these changes could be rationally understood. But in order to arrive at this understanding, a complete turn-about was necessary. Language had to be studied, not for what it ought to be, but for what it was. Grammar was no longer seen as a set of rules to be obeyed, but as a description of common usage at some specific point in time and space. It is probably not by chance that William Jones (1746-1794), who discovered Sanskrit, was a contemporary of Johann Beckmann (1739-1811). Although they possibly never heard of each other, both men achieved the same shift of point of view, the very shift on which every branch of science is founded. Similarly, botany or chemistry could only develop after it had been first decided that plants or substances should be studied for what they were, rather than for what they were useful to. The question then arises: why is it that philology, and later linguistics, developed so well and smoothly, comparatively, whereas technology

never really took off the ground?

Obviously, a good part of the answer lies with the dominant literary background of academics well into this century. People well acquainted with *belles lettres* might be more or less reluctant to adopt the new point of view of linguistics, but at least they did not lack the minimum of basic skills and knowledge necessary to make their choice. On the other hand, academics did completely lack this minimum of basic skills and knowledge as far as technics was concerned. Only technicians possessed it but technicians were not academics. And from the earliest times up to the present day, technicians have been able to become academics as scientists only, never as technicians. Insofar as the development of a new scientific discipline requires a sufficient number of people, both belonging to the academic world, and sufficiently acquainted with the new field, it is not surprising that things were comparatively easy for linguistics, and just about impossible for technology. No science can really develop without enough competent people.

That the lack of people at once academically and technically trained is really one essential cause of the non-development of technology, is further substantiated by another analogy with musicology. Musicology is much closer to technology than liguistics, to the point of being often considered as a branch of technology. It also resembles technology, in that musicians, like technicians, were barred from entering the academic world as such. But unlike technics, music is one of the fine arts, making it socially possible for musicians to develop an acadamic establishment of their own. So musicians have been able for some time to become academics without ceasing to be musicians, which made possible a pretty smooth development, first of the history of music, then of musicology proper. Today musicology is largely taken for granted, inasmuch as musicologists are not constantly obliged to defend or to justify themselves. Whereas the mere fact that Beckmann's or Mauss' technology is still denied the right to exist by scholars like Salomon shows how far we still are from a similar social acceptance of technology.

My contention here is that technology works, i.e. that it can produce, in its field, results of at least the same importance as linguistics or musicology in theirs — and perhaps more. This analogy with linguistics and musicology is of course not a proof, but neither would be a compilation of results, that would completely baffle

unacquainted readers. My problem here is no different from the main problem of technology: conviction is a two-way business; it requires as much effort from the reader as from the writer. People already well acquainted with the history of technics and of technology do not need this paper. For the other, all I can hope is that it is written in such a way as to make them stop and think, and wonder if something more important than expected is not at stake here. But they must know that nothing short of an honest attempt at studying results of technological research can convince them one way or the other.

One last question remains to be answered. Within the very broad (and admittedly somewhat vague) definition of technology as "a study of technics", two conceptions have been dealt with in this paper: Combarnous', and Beckmann's. Are these conceptions basically similar, or at least compatible with each other? And more generally: are there other such conceptions as well? how many? and it is possible to identify and to characterize them all?

An earlier survey (Sigaut, in press) of some of the literature listed by Guillerme, Sebestik and Morère in *Thalès* (1966) led to the conclusion that four main traditions of technological thought can be identified throughout history. Reduced to bare essentials, these four traditions can be described as follows:

1. TECHNOLOGY AS ENGINEERING (in French: *génie*)

This is the oldest tradition, since it can be traced back to hellenistic times, and plausibly earlier (Gille 1980). It is basically the endeavour to apply to technical processes whatever means of improvement are available, relying chiefly on mathematics and physical sciences. In fact, engineering still very much belongs to technics: it qualifies as technology only insofar as its emphasis on rationalisation is conductive to an explicitation of technical knowledge, which is chiefly evident when engineers take to writing, and more especially to teaching. As it were, engineering belongs to technology only by virtue of its teaching side. But this teaching side is of immense practical importance, and was the first step historically towards technology.

2. DESCRIPTIVE TECHNOLOGY

This is by and large Beckmann's technology. At the core of it is the idea that there is knowledge inside technics, and that this knowledge is worth studying for its own sake, like any other kind of knowledge. As far as I know, this idea was first expressed by Leibniz (quoted by Schuhl 1947: 31-32). Later on, everybody knows the celebrated texts of the *Encyclopédie* where both d'Alembert and Diderot insisted that arts, "par l'honneur qu'ils font à l'esprit humain", should not be regarded as inferior to sciences (art. "Art", ch."De la langue des arts"). So technical knowledge had to be given its proper place in intellectual culture. Of course it had first to be made explicit, by literary descriptions, drawings, etc. Developments of this idea by Beckmann and his successors are well known. But as descriptions piled up into more unwieldy compilations, the point of all the effort began to be lost. The sheer number and diversity of technics was clearly not to be mastered that way.

We know today, however, that in Beckmann's times, other sciences had to deal with objects as hopelessly diverse, seemingly, as technology had to: chemistry or biology, for instance. And those sciences succeeded in developing methods to handle and understand this very diversity. How is it that technology could not do the same? This may well be, I believe, one of the most important questions in the whole history of technology.

3. THEORETICAL TECHNOLOGY

It is certainly this question that Sebestik (1983: 42) alludes to when he concludes of Beckmann's technology that "the unity of its subject is, as further development shows perhaps, illusory and artificial". As a matter of fact, many early technologists were well aware of the problem. It is surely not by chance that Beckmann himself refers to the *Materia medica* in his *Entwurf* (1806: 13), and that so many of his successors still refer to biology today. Clearly, biology is a very relevant model for a would-be science trying to cope with an extremely large number of extremely diverse objects. But this parallel with biology was only one of the lines of thought explored in the search for a technical theory proper. Another, less well-known line,

was to look for a way to analyse techniques into a limited number of elementary items which could be recombined at will, and finally represented by signs or symbols for more efficient handling. This line of thought is not derived from biology, but rather from grammar, or algebra. It is epitomized by the names of Christoper Polhem (1661-1751), Charles Babbage (1792-1871) and Franz Reuleaux (1829-1905).

Polhem's idea (possibly anticipated by Leibniz) was that of a "mechanical alphabet", the "letters" of which were small-scale models of "simple movements", to be used by "mechanici" like letters by scholars in composing words and sentences. A number of Polhem's "letters" are to be seen at the Tekniska Museet in Stockholm, where this information was found. Babbage went a step further toward symbolozation in his essay "On a method of expressing by signs the action of machinery" (1826). He met with little success, however: only V. Willis a few years later, but chiefly Reuleaux in his *Theoretische Kinematik* (1875) attempted to use and develop similar methods.

I do not know whether there were other attempts at building up a theoretical technology after Reuleaux's, and what came of them, but I find this line of thought very fascinating. Reuleaux, and later Frémont, very clearly expressed their frustration at a mathematical treatment of mechanics that was unable to explain the mechanisms themselves, so that real explanations had perforce to be found in history (Reuleaux 1877: 2-3; Frémont 1917: Preface). Despite appearances I think that this frustration is still very much with us today.

4. TECHNOLOGY AS "TECHNIQUE DE L'USAGE CALCULÉ DES TECHNIQUES"

This formula is borrowed from Guillerme (1973). It conveniently describes a complex and diverse tradition of thought, where the emphasis is on systems analysis or operational research, that is on the proper use and combination of techniques rather than on the techniques themselves. Strictly speaking, the idea of looking at complex objects as systems is not new (the reference again is to biology). But there is no denying that the development of systems theory, games theory, operational research, cybernetics and computers from the

1930s and 1940s on, gave it a new momentum.

I shall not comment further on this line of thought, mainly because I do not feel really competent, and also because it is so recent that I find it difficult to see clearly what is going on and what will finally emerge. The best I can do is to refer to works like Couffignal (1963) or Guillerme (1973). More recently, the most elaborate attempt to build up a "General Technology" on these bases has been Ropohl's (1979).

In addition, some tentative characteristics of this fourth line of technological thought have been assembled in the following table, along with similar characteristics of the three preceding ones. I hope that this table, resulting from an earlier, more developed work (Sigaut, in press), will give the reader a better idea of what this whole paper is about, than any undue lengthening of the text. But I must point out that this table is only tentative: it is specifically made to be scribbled on, not just to be looked at.

* * *

By 1895, Durkheim had worked out his celebrated "rule" according to which "social facts should be considered as things".

This was not really a rule, but rather an axiom, and it may well be argued that it was not really new, either. But Durkheim undoubtedly gave it a new momentum which greatly helped sociology, and the social sciences generally, to be accepted as such by the scientific establishment. Whatever it may have been, Durkheim's "rule" is no longer a matter for serious discussion: it has now been accepted as a matter of course by generation after generation of scholars and students.

How is it possible, then, that ninety years later the similar and closely related idea that technical facts also should be considered as things is still so far from being accepted?

This is really the nub of the whole argument. This paper, and the earlier ones by Sebestik and Salomon, would not have been written at all, if the idea that technology is a science had already been as widely accepted as it had been for sociology, linguistics, etc.

Unfortunately perhaps, history is of only limited help in trying to understand why it was not so. In a way Salomon is right when he says that "the development of mechanisation and the industrial revolution

MAIN CURRENTS OF TECHNOLOGICAL THOUGHT (OUTSIDE ATHROPOLOGY)				
	(1) RATIONALIZATION	(2) DESCRIPTION	(3) THEORIZATION	(4) MODELIZATION
Scientific references	Mechanics, physical sciences	Natural history, biology	Grammar, Algebra	Systems theory, Cybernetics
Methods	Measurements, tests, calculations	Observations, comparative analysis	Symbolization	Operational research
Aims	Optimization (at material level)	Identification, classification	Derivation from axioms	Optimization (at organizational level)
Domain	Material production	Explicitation and transmission of knowledge		Decision, management
Social setting	Workshops, plants, farms, technical schools	University		Headquarters (corporations, army ...)
Agents	Engineers, technicians	Teachers, researchers, amateur historians, retired engineers, etc.		Executives, officers
Resulting idea of technology	Engineering, normative or prescriptive technology	Science of techniques		Technique of the use of techniques
Time of first development	Classical Antiquity	18th century	18th century	1930s & 1940s
Examples	Authors of manuals, since "Greek mechanicians"	Diderot (1713-1784) Beckmann (1739-1811)	Polhem (1661-1751) Babbage (1792-1871) Reuleaux (1829-1905)	N. Wiener R. Couffignal J. Guillerme G. Ropohl

impeded the establishment of technology as a specific university discipline" (p. 117). But just why things had to be that way is not clear. Indeed, it is not quite correct to say that technology had no future: the line of technological thought and research was not completely broken after Beckmann's immediate successors, but was carried on by people like Reuleaux, Frémont, Lafitte, Simondon, not to mention ethnologists and archaeologists like Leroi-Gourhan, etc. Neither is it correct to say that those people failed in their endeavours. Indeed, their work by no means conveys an impression of failure. Given the times and circumstances, they achieved no less, in any way, than the people whose works are now considered as classics just because they happened to have a strong following — Durkheim, for example, has become the object of a real cult, although many aspects of his thought appear much more obsolete by now than Espinas' or Reuleaux's.

Max Planck once said that scientists do not change their mind: they die, and are replaced by others. The history and sociology of science today confirm this rather pessimistic view. Acceptance of new theories, or of new paradigms, is a complicated process, where intrinsic "scientific" values are only one factor among many, and not necessarily the most decisive. Technology may be a superb case in point. By any standards, it has been quite as successful and productive as other sciences in a comparable state of development. And to any one who has practised it seriously enough, it can be much more.

There is no such thing as a failure of technology. There is a failure of the scientific community at large to see and understand the evidence. Why it is so is a matter for conjecture; but even if it was not, it would make no difference, because any explanations would simply be additional pieces of evidence, and would be no more clearly perceived nor better understood than any other. Technologists can only hope that this blindness will cease some day. There is nothing they can do about it but work on.

Notes

1. And by the way, what exactly is the difference between "a candle's light and that of an electric bulb"? At my level of scientific knowledge, there used to be none; in both cases, light is produced by the same physical process, incandescence.
2. And about as old as technological thought itself too. According to Lynn White jr. (1965: 129), the first book on the history of technics was written c. 1350 by a

Gulielmus Pastrengus. And it is well known that Polidoro Vergilio's *De rerum inventoribus*, published in 1499, was a best seller.

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