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ABSTRACT

This seminar paper explores the role that historians of technology can play in the reevaluation of the relationship between technical and social change. Historians of technology need to ask questions about the nontechnological aspects of society which have influenced technical change in the past. In the realm of ideas, historians should check whether the main normative and descriptive assumptions used by innovators were, in fact, dominant ideas in the societies in which they lived. In short, historians need to write a social history of the ideas that encouraged investigations of techniques, made the discovery of new techniques possible, and guided the uses of these techniques. As an example, the story of the relationship between the chemist Joseph Black and James Watt, inventor of the separate condenser for the steam engine, is presented. The story shows the integration of technology, society, and culture. The relationship between the men is examined for scientific discoveries that were transmitted between them, the general character of the society supporting their activities, and common areas of understanding and knowledge. In this case, an important technical innovation depended upon a close and friendly relationship between the men. (Author/ND)

TOWARDS A SOCIAL HISTORY OF TECHNOLOGICAL IDEAS: JOSEPH BLACK, JAMES WATT AND THE SEPARATE CONDENSER

By

Arthur Donovan

An Occasional Paper

on

Man/Society/Technology

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Preface

This paper was presented as one in a series of seminars on Man, Society, and Technology, conducted by the program of Technology Education at West Virginia University during the 1973 summer session. Over fifty individuals, including faculty and students from the university as well as individuals associated with the university through other institutions and endeavors, participated in the seminars.

The seminars were dedicated to a better understanding of the modes of inquiry, basic assumptions, principles, and concepts used by members of various disciplines and professions as they pursue answers to questions concerning the nature of man and technology in relation to the problems and issues associated with ecology, work, theology, law, medicine, politics, education, and economics; and questions concerning values, technological assessment and forecasting.

One overwhelming conclusion was the realization that the complex issues and problems associated with technology are related directly to decisions which are functions of value systems. Values require examination and reassessment. The educated citizen of tomorrow can not be trained as a narrow specialist nor can the humanist remain technologically aloof or illiterate. Education for the future may mean a rebirth of the renaissance man and perhaps a reevaluation of the technologies and humanities and the creation of a new interdisciplinary effort called the "techmanities."

The paper by Arthur Donovan, entitled "Towards a Social History of Technological Ideas: Joseph Black, James Watt and the Separate Condenser," provides in the setting of one event in the history of technology an exploration of the role historians of technology can play in the reevaluation of the relationship between technical and social change. In the process, Donovan identifies several important implications for education and society's view of intellectual endeavors.

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Arthur Donovan

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In a recent cartoon, a rumpled and exasperated father rebukes his disheveled son by shouting "You want to change the course of history? Then go get a degree and become a history teacher!" If only it was that easy. Those who write and teach history will particularly enjoy this highlighting of the ambiguous phrase 'the course of history', but having briefly savored the father's riposte, they will once again earnestly set out to determine, and perhaps change, the course of history. Although history may not be moving in any discernible direction and we may not be able to influence its flow in the least, in practice we are not fatalistic. We believe knowledge is power and we believe we can know something significant about the human past. In our lives, if not in our libraries, our most deeply held criteria of significance are determined by contemporary conflicts. Since our modern world has been largely molded by the overwhelming power of technology, it is therefore natural that the history of technology should today be of particular interest to those historians who, while often less forthright than young radicals, nonetheless harbor hopes of changing the course of history.

The history of technology is, however, an unusually complex field of study. It is charged with examining some of the most intricate and least well documented products of human society and it must tell its story without relying on the national and geographic boundaries which make traditional political and cultural history relatively manageable. Faced with such a difficult and comprehensive responsibility, the historian of technology often pleads that he must devote all his attention to the factual record which fleshes out his narrative. There is, however, a reluctance to accept such disclaimers, for there is an urgency about the history of technology that is totally absent in comparable fields such as the history of art and architecture, the history of music and even the history of science. Culture critics and thinkers of all sorts bombard historians of technology with philosophical and technical questions in the hope that by increasing their knowledge of this most fundamental of subjects they will be able to cast light on our perennially inadequate understanding of economics, politics, cultural change, and the progress of technology itself. Historians of technology, by virtue of their subject rather than their achievements, are frequently offered the prophet's robes. It is a heady temptation, one which makes the hard work of historical research seem drab. Rather than having to struggle to establish the significance of his subject, the historian of technology must resist intellectual intoxication by practicing verbal abstention and theoretical self-denial. If the history of technology is to flourish, its practitioners will have to learn to ride Roman style, with one foot firmly anchored to the plow horse of detailed scholarship while the other rests lightly on the dancing stallion of social and cultural speculation.

Indeed the history of technology will only remain vital if its devotees are able to feel the force of contemporary questions while meeting the standards of scholarship which must be satisfied if their interpretations are to be believed. Historians, like all those engaged in cultural labor, are at bottom articulators. They develop symbols and concepts to clarify and interpret the collective experiences of the groups they live in and among. Such clarification and interpretation becomes especially important when our received ideas, upon which we found our expectations and with which we construct our initial interpretations of experience, begin to appear inadequate in the face of the demands placed upon them. The urgency which presses upon all those who study technology today springs, I believe, from a deep and threatening fissure in our received ideas about the nature of technology. For nearly a century our analysis of social change has taken as its point of departure technical change in the means of production. The commonplaces of our language and the common sense of our culture point to technology as the engine of industrialization and modernization. East and West, in the industrialized nations and in the so-called underdeveloped nations, in the socialist countries as well as in those ruled by monopoly capital, technological innovation has been seen as the key to our understanding of the modern world and as the Aladdin's lamp whose genie has the power to singlehandedly fashion a better life for all. This, in a general sense, I take to be our received idea of technology. It is an intellectual inheritance which has been criticized in the past but which has survived, like an estate defended by a well-drawn will, down to the present. But now, as we all know, this conception of technology is under heavy attack. Like laissez faire, the doctrine of laissez innové is being challenged (see McDermott). Must we continue to encourage the growth of technology while passively accepting the cultural devastations and social dislocations which attend the unregulated introduction of new techniques of production? It seems to me that more and more people are answering this question with a negative. The wide spread concern with environmental impact, the revolt of the 'third world' against economic imperialism, and the flourishing of communitarian social movements in industrialized nations indicates that the relationship between technology and social change is being radically revalued. In the future I think that the development and utilization of new techniques of production will be increasingly governed by the consensus of all those directly affected by the changes involved. And if in fact the rate and direction of technological change is brought under democratic control, then our theories about the relationship between technological innovation and social change will have to be reconstructed to encompass the new state of affairs. Once having done this, we will no longer be able to simply assume that in seeking to explain social and cultural change one should begin with an account of changes in the mode of production.

Historians of technology can play a constructive part in this ongoing revaluation of the relationship between technical and social change if they are willing to ask the right questions of their material. We are now beginning to insist that those most affected be allowed to control the introduction of new technologies and we would like to know if similar demands have been raised and satisfied in the past. More generally, we need to identify the non-technological aspects of society which have influenced technical change in the past. In the realm of ideas, the chief concern of the case I will turn to shortly, we want to know if the main normative and descriptive assumptions utilized by innovators were in fact dominant ideas in the societies in which they lived. Can we, in other words, write a social history of the ideas which encouraged the investigation of techniques, made the discovery of new techniques possible, and guided the uses to which these new techniques were put? For instance, in thinking about the relationship between the chemist Joseph Black and James Watt, the inventor of the separate condenser for the steam engine, we should not only look for particular discoveries that were clearly and purposefully transmitted from the scientist to the inventor or vice versa. We should also look at the general character of the society which brought these men together and supported their activities and we should try to identify those areas of understanding which were their common property and which each man utilized in his own way. By proceeding in this way we can emphasize the uniqueness of each individual's achievement without falsely separating his brilliance as an inventor from his experience as a man.

What role did contemporary science play in the invention of the separate condenser, that modification which has been called the most important technical development in the Industrial Revolution? According to John Robison, one of James Watt's closest friends, Watt invented the separate condenser by applying Joseph Black's theory of latent heat to the study of the steam engine. Watt himself objected to this account of his invention, for while he was grateful to Black for his help and encouragement, he was not about to have his achievement reduced to a rather straightforward application of a general principle. But Watt's opposition did little to slow the spread of Robison's story. Science discovers the laws of nature and technology applies them to the service of man, to paraphrase the motto inscribed in the dome of Chicago's Museum of Science and Industry, and this notion was so pervasive in the nineteenth century that Robison's story was accepted because it conformed to the general understanding of the relationship between science and technology. It was the nineteenth-century view of technology that transformed Robison's account, which sprang from a desire to honor Black, his teacher and predecessor, into the legend which Donald Cardwell has recently so aptly described and criticized (Cardwell, chapter 2).

The growth of the history of science in the last few decades has necessarily resulted in a good deal of demythologizing. Armed with Watt's own statements and aware of the physics of the steam engine, several historians have pointed out that Robison's story should be transferred from the history of technology to the history of enthusiasm. (see Fleming, Smeaton). And yet, there is a danger involved in this kind of revision. Robison's story contains an important kernel of truth, namely that there was a close relationship between Black's science and Watt's invention. While we now know Robison misrepresented the essence of this relationship, we must be wary of accepting a revision which postulates too great a distance between Black's and Watt's achievements. In our day it is all too easy to think of technology as an autonomous activity, one which generates whatever kinds of understanding it needs. But this supposed autonomy is neither beyond question in our society nor was it characteristic of the setting in which Watt worked. Rather than abandoning the Robison legend, we should modify it in a way which is both true to the historical and physical facts and which illuminates our own emerging understanding of technology.

James Watt arrived in Glasgow in 1754 (Muirhead, passim). Eighteen years old and eager to make his own way in the world, he spent his first year living with his maternal relations, the Muirheads, while seeking a position in which he could acquire the skills needed to become a mathematical instrument maker. His choice of trade reflected both his own mathematical proclivities, which seem to have been a characteristic of the Watts, and his intimate knowledge of the nautical apparatus and instruments sold by his father.

In Glasgow Watt had the good fortune to be introduced to several members of the university faculty through his relative George Muirhead, who was then professor of Latin. Although James never attended a course of lectures given in the University, he did become friendly with Dr. Dick, the young professor of natural philosophy who had previously been Black's closest companion when he was a student in Glasgow. When Professor Dick heard of Watt's interest in mathematical instruments, he strongly advised him to learn his trade in London and he further encouraged him by supplying him with several letters of introduction. In June 1755 Watt set off on horseback for London. At first he encountered considerable difficulty in finding a master, for the few skilled instrument makers in London were reluctant to dispense with the customary seven years apprenticeship. With Dick's letters, however, Watt gained the attention and then the friendship of James Short, a Fellow of the Royal Society and a celebrated maker of reflecting telescopes, and through Short he obtained a position with John Morgan, a maker of Hadley quadrants. After a year of arduous work and frugal living, Watt returned to Scotland to practice his newly acquired skills. Shortly after his arrival in Glasgow, Professor Dick asked Watt to repair a set of astronomical instruments which had been given to the University, and a year later Watt was given a shop and an apartment in the university buildings and was designated "mathematical instrument maker to the University."

Watt met John Robison soon after he moved into his new accommodations. Robison was a bright young man who had recently taken his degree in Glasgow and was evidently at loose ends. He soon discovered that Watt was a man of the highest ability and an enthusiastic investigator of mechanical questions, and the two young men quickly formed a friendship which lasted until Robison's death.

Late in 1756 Joseph Black returned to Glasgow to become professor of anatomy and botany and lecturer in chemistry. He was, no doubt, soon introduced to Watt by their mutual friend Professor Dick. Black was greatly impressed by Watt's quick scientific mind and unusual mechanical ability, and he soon asked him to construct several pieces of experimental apparatus for him. Black enjoyed visiting Watt's workshop and it was there that Robison first met his future mentor. Throughout 1758 these three young philosophical bachelors thrived upon each others company. Black was then trying to think of ways to extend and test his theory of latent heat, Watt was struggling to make a go of it as an instrument maker, and Robison was casting about for a situation which would oblige him to fasten his agile mind to a concrete set of problems. Serious tasks all, but evidently pursued with an enthusiasm which made light work of heavy thinking. As an example of the way in which Watt threw himself into challenges he found appealing, Robison later recalled that "a Mason lodge in Glasgow wanted an organ. The office bearers were acquaintances of Mr. Watt. We imagined that Mr. Watt could do any thing, and although aware that he did not know one musical note from another, he was asked if he could build this organ. . . .He said yes. But he began by building a very small one for his intimate friend Dr. Black (Robinson and McKie, 259-60)."

Late in 1758 Robison left Glasgow, but when he returned after an absence of four years, he was immediately welcomed back into the philosophic circle. As Robison later said of his friendship with Watt, "I had had the advantage of a more regular education: this frequently enabled me to direct or confirm Mr. Watt's speculations, and put into a systematic form the random suggestions of his inquisitive and inventive mind. This kind of friendly commerce knit us more together, and each of us knew the whole extent of the other's reading and knowledge. I was not singular in this attachment. All the young lads of our little place that were any way remarkable for scientific predilection, were acquaintances of Mr. Watt; and his parlour was a rendezvous for all of this description (Robinson and McKie, 257-8)." Although Black was not one of the 'young lads', Robison said that upon his return he found Watt "most intimately connected with Dr. Black, and continually speaking of his lectures and doctrines (Robinson and McKie, 379)." And Watt himself told Robison that "every thing I learnt from him [Black] was in conversation and by doing small mechanical jobs for him. These conversations and those I had with you served to give me true notions in science and to develope the powers of my mind (Robinson and McKie, 416)."

What significance should we attach to the friendship between Black, Robison and Watt? First, it should be pointed out that all the statements given above refer to their relations before 1765, the year in which Watt invented the separate condenser. Second, it is clear that these men were drawn together by their common interest in a particular set of problems and that discussion of those problems dominated their conversations. These three men constituted a self-selected and self-supporting research team of extraordinary historical importance. Surely it would be artificial on our part to try to erect barriers between the conceptual foundations of Black's natural philosophy and Watt's mechanical investigations. We can, of course, distinguish between Black's evident desire to construct a general theory of chemistry and Watt's clearly stated ambition to be a successful craftsman and engineer, but in so far as their activities depended upon a common understanding of nature, we must assume that they were well informed about each others thoughts. The question is not, therefore, whether Black's scientific knowledge played a part in Watt's invention, but whether we can correctly identify and specify the part that it played.

Sometime in 1758 Robison turned Watt's attention to the steam engine, a device, Watt admitted, "of which I was then very ignorant (Robinson and McKie, 410)." Watt built a small model which proved disappointing, and the investigation was soon abandoned. Five years later John Anderson, who had succeeded Dr. Dick as professor of natural philosophy in Glasgow, asked Watt to repair the university's demonstration model of the Newcomen engine. At first, Watt later recalled, "I set about repairing it as a mere mechanician, and when that was done and it was set to work, I was surprized to find that its boiler could not supply it with [enough] steam, though apparently quite large enough (Watt's notes, published in Robison II:113)." Surprise quickly became a consuming curiosity as Watt pressed on in his analysis of the model steam engine. He puzzled over "the imense Quantity of fuel it consumed in proportion to its Cylinder," (Robinson and McKie, 434) and wondered where all the heat given off by that fuel was going. Through studying the operation of the model Newcomen engine, Watt recognized the need for a heat analysis of the steam engine, and it was this approach to the problem which enabled him to invent the separate condenser.

But how else could he have analyzed the steam engine? For us, the steam engine is a heat engine by definition and its operation is explained by the laws of thermodynamics. But Watt's predecessors thought of it as a mechanical engine and they explained its operation in terms of the pressure exerted by the elastic atmosphere (see Cardwell, 49-59, 54). Different sides of the same coin, you may say, but the improvements suggested by the two views are fundamentally different. Watt's decision to undertake a heat analysis of the steam engine thus stands as the fundamental intellectual shift that led to the discovery of the separate condenser. Yet I suspect that Watt was not even aware of the novelty of his approach. For years he had been listening to Joseph Black talk about the central role of heat in chemistry and he knew that Black and his teacher William Cullen both believed that chemistry was the most practical branch of natural philosophy. Thus when Watt began studying the steam engine, he naturally saw it as a heat engine. He found this approach natural not because of the nature of the engine itself, but because it was the dominant approach to the study of physical nature in the immediate context of his life. Here, in the largely unconscious social determination of Watt's conceptual framework, we find the crucial link between science and technology.

There is other evidence which indicates that Watt had Black's specific contributions to the study of heat in mind during his initial analysis of the steam engine. To reduce the amount of heat being lost, Watt sheathed his boiler with wood and he constructed a wooden cylinder for his engine. He also used the results of Black's study of specific heats to determine the quantity of heat absorbed by different metals when heated over a given range of temperature (Robinson and McKie, 435-6, 438). Watt discovered that a great deal of heat is lost to the water used to condense the steam in the cylinder of the Newcomen engine. The condensing water would not drain out of the cylinder until it had become nearly boiling hot, and so long as it remained in the cylinder, the steam admitted to start the next cycle was weak (Robinson and McKie, 436). He suspected that a great deal of steam was being condensed before it had done any work, and he tested his suspicion by measuring the volume ratio between steam and water. Desaguliers, one of the leading English natural philosophers of the first half of the eighteenth century, had concluded that "water in boiling is expanded 14000 times," (Desaguliers, 16-17) and William Cullen, Black's teacher and the leading chemist in Scotland during the middle decades of the century, had used Desaguliers' figure in his lectures without questioning its correctness. On the basis of his own experiments, however, Watt determined "that there was a great error in Dr. Desaguliers' calculations . . . on the bulk of steam" and that the correct figure was between 1600 and 1800, not 14000 (Robison, II:115). Watt then calculated the volume of steam produced by his boiler and concluded that "the quantity of steam used in every stroke of the [Newcomen] engine [is] several times the full of the cylinder." (Robinson and McKie, 437; Robison, II:116) He had determined, in other words, that a great deal of heat was being lost through the condensation of steam in the first part of the cycle.

Watt knew that most of this lost heat was being used to warm the heavy metal cylinder that had been cooled by the condensing water at the end of the previous cycle. Although he had a rough idea of the amount of steam needed to run the engine, he was still puzzled because "the Quantity of water used for Injection in fire engines was much greater than I thought was necessary to Cool the Quantity of water contained in the Steam to below the boiling point." (Robinson and McKie, 438-9) He therefore performed two more experiments. In the first he mixed measured quantities of boiling hot water and cool water and noted the temperature of the mixture. In the second he condensed steam by passing it into a measured amount of cold water and then noted the resulting rise in temperature and the increase in the quantity of water. When he compared the results of these experiments, he discovered that water in the form of steam contains a great deal more heat than water heated to the boiling point. Upon asking Black what he made of this fact, Watt was told that he had encountered the phenomenon of latent heat, a property of heat that Black had been studying and describing in his lectures for several years. Unlike Black, however, Watt was looking for a way to improve the heat efficiency of the steam engine. His independent discovery of the latent heat of steam simply meant that there was even more heat being lost in the condensation of steam than he had suspected.

Our record of Watt's thoughts during this period is sketchy, but we do know that the invention of the separate condenser did not follow directly from his discovery of the latent heat of steam. Watt realized that the amount of heat trapped in the latent state is determined by the fixed laws of nature, rather than by a correctible flaw in the steam engine. He therefore again turned his attention to the heat lost in cooling the cylinder during the condensation of the steam. Why, he apparently wondered, must the cylinder of a fully loaded engine be cooled down to around 100 degrees Fahrenheit? This is far below the boiling point of water, yet if the flow of condensing water is shut off before this temperature is reached, the engine can only be operated under reduced load. We of course know that so long as the temperature of the cylinder remains above 100 degrees, the water in the cylinder continues to boil in the vacuum created by the condensation of the steam, thereby creating a back pressure which opposes the atmospheric pressure acting on the external face of the cylinder. But how was Watt to know about boiling under reduced pressure? His own experiments were hardly of the sort that would have brought this phenomenon to his attention and he never claimed to have discovered it himself. This phenomenon had, however, been the subject of intense study by Cullen, Black and Robison in the decades which preceded Watt's invention, and Watt himself said that for his knowledge of boiling under reduced pressure he "was indebted to the Experiments of Dr. Cullen on the boiling of Ether <u>in Vacuo</u> and some conversations I had on the subject of that experiment with Dr. B[lack] and Mr. Robison." (Robinson and McKie, 418. See also Cullen; Black, I:161-2)

Once he had grasped the relationship between the temperature of the cylinder, boiling under reduced pressure, and back pressure on the piston, Watt was able to clearly formulate his fundamental problem. "To make a perfect steam engine," he said, "it was necessary that the cylinder should be always as hot as the steam which entered it, and that the steam should be cooled down below 100 degrees in order to exert its full powers. The gain by such construction would be double: - first, no steam would be condensed on entering the cylinder; and secondly the power exerted would be greater as the steam was more cooled." (from Watt's "Plain Story", Muirhead, 87) Such an engine would be perfect because it would extract as much mechanical work from a given quantity of heat as the laws of nature would allow. But how could one have a cylinder which stayed hot and yet was cooled down below 100 degrees? The answer, as Watt discoverdd during his famous Spring walk on the Glasgow Green, was to add a second cylinder to the engine; a separate condenser.

I have tried to illustrate, in so far as time would allow, that in one particular historical instance the invention of an important technical innovation depended upon a close and friendly relation between a man interested primarily in natural philosophy and another interested primarily in practical improvement. At the risk of seeming to generalize from a single example, I will go further and admit that I attach a great deal of significance to other aspects of this case. Black and Watt lived in a society which understood that there is a difference between the pursuit of understanding and the pursuit of improvement. They had the good fortune to be born into a culture which did not elevate the philosopher and demean the mechanician, or vice versa. Although no utopia, Scotland during the latter half of the eighteenth century nourished an integrated and balanced cultural life. Education at the primary level was designed to insure that all members of the nation were equipped with the elementary skills needed to defend their liberties and to make their way in a society open to talent. At a more advanced level, the universities were committed to the development of those systems of political and social thought and those areas of specialized knowledge upon which the future growth and guidance of the nation depended. I believe that the world of Black and Watt, although swept away by the dual revolutions - French and Industrial - that erupted during the last years of their century, remains an instructive historical example of the happy integration of technology, society and culture. If historians today wish to play a part in articulating the new understanding of technology and society now emerging, they should pay particular attention to the comparable integrative aspects of the cases they study.

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