CHARLES BABBAGE—HIS LIFE AND WORKS
IN THE HISTORICAL EVOLUTION OF MANAGEMENT CONCEPTS

DISSEYATION
Presented in Partial Fulfillment of the Requirements
for the Degree Doctor of Philosophy in the
Graduate School of The Ohio State
University

By
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CHAPTER I

INTRODUCTION

Objective

The objective of this dissertation is to evaluate the contributions made by Charles Babbage to the historical development of industrial management concepts.

Need For The Study

In order to understand the evolution of industrial management concepts it is essential that we improve our knowledge of their past. Although "there is no set of observations conceivable which can give us enough information about the past of a system to give us complete information as to its future," we can improve our understanding of the present and better our prediction of the future by more accurately knowing the past.

An insufficient amount of true research has been done on the historical development of industrial management concepts. Charles Babbage is increasingly recognized as an early contributor to management concepts, but he has been predominantly represented as having been a small, isolated, impractical case. His works are thought to have died


out without significantly influencing later developments. This is not in accordance with the facts uncovered by this research.

The evidence presented in this dissertation proves false the classical interpretations of management history, which, for the past half century, have professed that the foundations of management were made at the end of the 19th Century, with no significant work being done prior to that date. Furthermore, the evidence in this dissertation

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shows how the development of industrial management concepts has actually been evolutionary over hundreds of years and not revolutionary with a sudden beginning after 1880.\(^5\) It proves that "many management principles have ancient origins."\(^6\)

In the field of management history, many persons have been misled by blindly following the erroneous teaching of those who preceded them. Many have been led astray by a few.\(^7\) This dissertation is only a start.

\(^4\) cont.


\(^5\) Drury, op. cit., pp. 20 ff. is an example of the errors made regarding the historical development of industrial management concepts. He concluded there was a revolutionary growth since he "statistically demonstrated" the enormous growth of the literature on "scientific management" and "efficiency" after 1910. Actually all he proved was the increased use of these two terms and not a sudden growth of new concepts. If the use of terms such as "commercial organization" or "commercial management" had been tabulated, contrary conclusions could have been reached.


\(^7\) Fredrick W. Taylor and some of his followers probably did the most to cloud the picture of the true historical development of industrial management concepts. That story is too long to cover in this dissertation, but some material on it will be found in Chapters VIII and IX.
in correcting past misconceptions and only begins to develop a better perspective of industrial management history. Much still remains to be studied in this important area of the background of ideas. If this dissertation can encourage others to re-examine their teachings and add further perspective to the history of management concepts, it will more than repay the years of study which have gone into it.

Methods and Limitations of the Study

This dissertation sets forth the industrial management concepts of Charles Babbage and evaluates some of their possible sources and later influences. The story of his life, including the circumstances surrounding his famous calculating machines, is reconstructed and described in order to place his ideas in proper context.

Charles Babbage was selected as the focal point of this study for the following reasons: first, some of his writings covered a wide range of industrial management concepts; second, his ideas have been

Babbage spent a great deal of time and energy on his calculating machines. They gained him his greatest recognition and deepest disappointments. For this work he is today recognized as the forefather of the modern digital calculators. Ref. the following:


Cf., Chapters V, VI, and VII of this dissertation.
considered far in advance of their time; third, the importance of his works to later developments in the management movement has not been recognized by the writers of management history.

To keep the study from becoming boundless, research has been limited to material written in English and French and available in libraries in the United States. Concepts which were used in the management of industry, either in Babbage's time or afterwards, are included in the meaning of the terms, "industrial management concepts."

Although Babbage was internationally known and was regarded as one of the most eminent scientists of his time, there is no published biography of him. The best single source of information about his life is his last book, Passages from the Life of a Philosopher, but even this contains errors and much personal bias.

The research for this dissertation has located many facts of Babbage's life and many sources of his ideas; but undoubtedly others still remain to be discovered, for he led an unusual life. Some idea

10 Cf. ante, footnote 3.

11 Cf. ante, footnote 4.

12 The Times. London: No. 15, Oll, Friday, November 16, 1832, p. 3.


of the versatility and breadth of interest of this fascinating character may be obtained by noting the people with whom he associated and the subjects on which he wrote.

Babbage is known to have associated with celebrities such as the following: Nassau Senior, Lord Macaulay, Thackeray, Lady Lovelace, Charles Dickens, Samuel Rogers, Emperor Napoleon and Empress Eugenie, Sir John and Sir William Herschel, George Peacock, the Duke of Wellington, Earl of Rosse, Laplace, Poisson, Fourier, Charles Darwin, Joseph Whitworth, Richard Jones.

16 Ibid., p. 42.
17 Ibid., p. 50.
18 Ibid., p. 52.
20 Ibid., p. 29.
21 Ibid., p. 75.
22 Ibid., p. 75.
23 Ibid., p. 197
26 Babbage, Charles Passages. op. cit., p. 433.
Michael Faraday, T. R. Malthus, and many others.

The following are "some of the subjects on which he wrote—Glacier; Uniform Postage; Parcel Post; Submarine Navigation; Magnetic and Electric Rotations; Light-houses; Light-signals; Telegraphs; Geology; Miracles; Monopolies; Locks and Lockpicking; Division of Labour; Taxation; Commerce; Wood-engraving; the Diving Bell; Games of Skill; besides numerous contributions to Astronomy, Mathematics, and Mechanics." In one book alone, On the Economy of Machinery and Manufactures, Babbage wrote on subjects such as: the importance of tools, machines, and mass production; the importance of the division of labor, both mental and physical; a basic marginal productivity theory; factors of plant location and reasons for large factories; profit sharing; and many other topics important to industry.

Organization of This Study

The material in this dissertation is organized into ten chapters. Chapter I, Introduction, presents a statement of the objectives, need for the study, methods and limitations of the study, and organization of the study.

The life of Charles Babbage is presented in Chapters II, III, and IV essentially as it occurred—in chronological sequence. Although there

27 Dodge, W. S. "A Philosopher and His Friends." Lakeside Monthly, Chicago: IX, p. 239.
28 Loc. cit.
are not three completely distinct phases of his life, the material is divided into three sections for the ease of the reader. Chapter II, The Developmental Years, covers the first thirty years of his life. Chapter III, Years of Achievement and Qualified Success, tells of his accomplishments between the ages of 30 and 40. Chapter IV, Decline and Disillusionment, relates the events of the last 40 years of Babbage's life.

Chapters V, VI, and VII present the industrial management concepts of Charles Babbage. The presentation of these concepts is done largely in Babbage's own words. Since the review of Babbage's important book, On the Economy of Machinery and Manufactures,\(^{31}\) is rather lengthy, it is divided into two parts on a basis similar to Babbage's own division of the book. Chapter V, The Economy of Machinery and Manufactures, Section I, is devoted to "the mechanical part of the subject.\(^{32}\) Chapter VI, The Economy of Machinery and Manufactures, Section II, contains "a discussion of many of the questions which relate to the political economy of the subject."\(^{33}\) Chapter VII, Babbage's Industrial Management Concepts in Other Writings, covers his industrial management concepts which appeared in his other writings.

Chapter VIII, Background and Sources of Babbage's Industrial Management Concepts, presents information regarding some of the events


\(^{33}\) Ibid., p. 2.
and previous writings which influenced Babbage's thinking concerning these concepts. This chapter places Babbage's writings in context with what preceded him.

Chapter IX, Influence and Significance of Charles Babbage, evaluates the influence and significance of Charles Babbage to other people and later developments.

Chapter X, Summary and Conclusions, is a summary of the dissertation and the conclusions which are drawn from it.

Chapter Summary

The objective of this dissertation is to evaluate the contributions made by Charles Babbage to the historical development of industrial management concepts.

In order to fully understand our industrial management concepts it is helpful to know their evolution. Not enough of true research has been done on the historical development of industrial management concepts and this dissertation only makes a beginning in that direction, by studying a small segment of the past—the life and works of Charles Babbage, a pioneer industrial philosopher.

This dissertation finds that Charles Babbage was not an isolated, impractical case, far ahead of his time, but, contrary to present teachings, he was part of the evolutionary development of industrial management concepts which has been taking place over hundreds of years. The true growth of management concepts has not been revolutionary with a sudden beginning at the end of the 19th Century as has been commonly believed.
The research for this dissertation has been limited to material written in the English and French languages, and available in libraries of the United States.

Although Babbage was internationally known and regarded as one of the most eminent scientists of his time, there is no published biography of him. The emphasis of this study is on Babbage's industrial management concepts, but the other aspects of his unusual life are indicated in order to place his ideas in proper context.

Following this introductory chapter, this study presents his life, chapters II, III, and IV; his management concepts, chapters V, VI, and VII; background and sources of his ideas, chapter VIII; his influence and significance, chapter IX; and a summary and conclusion of the research, chapter X.
CHAPTER II

THE DEVELOPMENTAL YEARS

Introduction

Charles Babbage was born on December 26, 1792 near Teignmouth in Devonshire, England. 1 For convenience of presentation the first thirty years of his unusual life are considered to be the developmental years. It was during these years that Babbage grew up, became educated, and formed many of his ideas. During these first thirty years Babbage made outstanding contributions to the progress of English science but his later years contained his best known works.

Ancestral Background

Babbage knew little of his ancestry and cared even less, for he wrote, "my knowledge of the history of my family is limited to the fortunate omission of my name from the role of William's


Although the year of birth of Charles Babbage is sometimes given as 1791, a careful crosschecking of the most authoritative sources confirms the year 1792.
followers. Those who are curious about the subject, and are idlers, may, if they think it worth-while, search all the parish registers in the West of England and elsewhere. He further said that he possessed no evidence that he was descended from Cain but considering his "inveterate habit of contriving tools" he whimsically proposed that he must be descended from Tubal Cain, a great worker in iron.

Recent generations of Babbages were goldsmiths and Charles Babbage's father, Benjamin Babbage, was a banker of the firm Praed, MacWorth & Babbage. He was apparently successful enough to leave Charles a private fortune of sufficient magnitude to permit him to pursue many of his expensive interests in later life.
Charles Babbage and his parents were Protestant, for "being born at a certain period of history, and in a certain latitude and longitude, of course followed the religion of their country."  

Boyhood and Early Education

Babbage's childhood was apparently spent in Devonshire and in London. At least twice, at ages five and ten years, he suffered severe illness and his early teachers were requested to pay more attention to restoring his health than to his education. Perhaps this freedom from routine was partly responsible for his developing an independence of spirit and thought.

Babbage's early schooling was started at about five years of age with a clergyman at Alphington, near Exeter, Devonshire, England. This was followed by three years (probably his early teens) at a school in Forty Hill, near Enfield, where one of Babbage's roommates was Frederick Marryat, later Captain Marryat, a popular

7 Babbage, C. op. cit., p. 7.
8 Babbage, C. op. cit., pp. 8-10.
Annual Register, op. cit., p. 159.
9 Babbage, C. op. cit., p. 10.
10 Loc. cit.
A. M. C. op. cit., p. 304.
Due to the fact that this school master, Reverend Freeman, was interested in mathematics, and because a copy of Ward's, *Young Mathematical Guide* was available, Babbage began his study of mathematics at this school. He carried this interest to the extreme, rising sometimes at 3:00 o'clock in the morning to study by the light of the fire. Eventually, however, others joined in this escapade and soon they "let off fire-works in the play-ground, and were of course discovered and reprimanded."

After leaving this school, Babbage was for a few years under the care of an "excellent clergyman" in the neighborhood of Cambridge. Here frequent contact occurred with the crusading churchman, Reverend Charles Simeon, and many of his enthusiastic disciples. Among the teachings at this school were probably Reverend Simeon's ideas of

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11 Loc. cit.


14 Ibid., p. 23.


composition, which may have helped Babbage develop the ability to express himself in excellent generalizations.\textsuperscript{17} This was one of the characteristics of his later best writings, including his book, \textit{On the Economy of Machinery and Manufactures}.\textsuperscript{18}

In later years, Babbage said that even as a boy he always believed "that occupation of the mind is such a source of pleasure that it can relieve even the pain of a headache." When bothered with a toothache he said he used this idea and relieved the pain by concentrating on reading books like \textit{Don Quixote} or \textit{Robinson Crusoe}.\textsuperscript{19}

Other boyhood activities included an unsuccessful attempt to make the devil appear for an interview. To call out the devil young Babbage had retired to a deserted garret and repeated the Lord's Prayer backwards while standing in a circle made with his own blood. Since the devil did not appear Babbage was not too sure whether or not he really existed.\textsuperscript{20}

On another occasion Babbage, in order to determine what follows after death, bargained with his best boyhood friend that whoever died

\begin{itemize}
\item \textsuperscript{17} Simeon, Charles Claude's \textit{Essay on Composition of a Sermon}. London: James Cornish, 1844, p. ix.
\item Babbage, C. \textit{op. cit.}, p. 23.
\item \textsuperscript{18} Babbage, C. \textit{On the Economy of Machinery and Manufactures}. London: Charles Knight, 1832.
\item \textsuperscript{19} Babbage, C. \textit{Passages, op. cit.}, pp. 14-15. Frank B. Gilbreth seems to have been impressed by the italicized portion of this passage for he marginally noted it. Ref, Gilbreth's personal copy in the Gilbreth Collection, Purdue University.
\item \textsuperscript{20} Babbage, C. \textit{Passages, op. cit.}, pp. 10-14.
\end{itemize}
first should reappear to the survivor. After the friend's early
death, Babbage spent a sleepless night waiting in vain for the
friend's appearance. 21

Another boyhood incident involved an attempt to construct a
simple mechanism to enable one to walk on water. The mechanism not
only failed but almost proved disastrous by nearly drowning young
Babbage. 22

Babbage's early formal schooling was completed at Totnes,
Devonshire where he was privately tutored in his classical studies. 23
He also continued his interest in mathematics by reading Humphrey
Ditton's Fluxions, Madame Agnesi's Analytical Institutions,
Woodhouse's Principles of Analytical Calculation, and Lagrange's
Théorie des Fonctions. Thus, when he entered Cambridge, Babbage was
already fairly accomplished in mathematics. 24

While at Totnes, Babbage tried unsuccessfully to develop a
dictionary of universal language. 25 This pastime may have led to his
later interest in deciphering and his compilations of various un-
usual dictionaries. 26 Little else is known of Babbage's early life,

21 Ibid., pp. 15-16.
22 Ibid., pp. 206-207.
23 Ibid., p. 25.
25 Ibid., p. 25.
26 Ibid., pp. 235-241.
"for this was one of the subjects on which he was of his own choice reticent." 27

University of Cambridge

Babbage was admitted to Trinity College, Cambridge in the spring of 1810 and took up his residence there in October of the same year. 28

Except in the area of chemistry and mathematics there is very little specific information available on Babbage's education at Cambridge. However, the personal contacts which Babbage acquired at Cambridge were to have considerable influence on his later life. It was here that he probably began his close friendship with John Herschel, the only child of the famous astronomer, William Herschel. 29 (John Herschel was to become a leading scientist of England and to have a great influence on the life of Charles Babbage.)

At Cambridge both Babbage and John Herschel came under the influence of Smithson Tennant, a professor of chemistry who encouraged both in their studies of chemistry. 30 Both young men set up their own

27 The Athenaeum, op. cit., p. 564.


30 Babbage, C. Passages, op. cit., p. 38.
chemical laboratories and helped Smithson Tennant with his demonstrations. Both might have pursued these interests further, but for the untimely death of Mr. Tennant in 1814. However, another prominent chemist, and good friend of Mr. Tennant, Dr. William Hyde Wollaston, did continue to influence and advise Babbage and Herschel.

At this time, "for a variety of causes, not very easily understood, mathematical analysis had not made the advancement in England which had been so remarkable on the continent ever since the death of Newton. The Cambridge professors and teachers acted as if they had a vested interest in the powerful geometry of the past; many of them were possessed of vast mental capacity, but they continued to encumber themselves with an old fluxional notation, and ponderous methods, which had long been discarded by the philosophers abroad."

31 Loc. cit.


32 Babbage, C. Passages, op. cit., p. 38.

33 Babbage, C. Passages, op. cit., p. 42.

34 A. S., op. cit., p. 125.
Upon entering Cambridge, Babbage looked forward to receiving help from the tutors and lecturers. When they were unable to answer his questions and professed no interest in anything outside their antiquated routine, Babbage acquired a "distaste for the routine of these studies of the place, and devoured the papers of Euler and other mathematicians, scattered through innumerable volumes" of the journals of the leading European scientific societies. This independent study probably increased Babbage's knowledge of current European scientific developments as well as furthered his independence of thought and investigation.

Analytical Society

The disinterest of the majority of the Cambridge faculty in improving their mathematics led Babbage and some of the other best students of mathematics at Cambridge to form, in 1811, the Analytical Society. These fellow students included Michael Slegy, Edward Bromhead, John Herschel, George Peacock, Alexander D'Arblay, Edward Ryan, Robinson, Fredrick Maule, and several others. The Society hired a meeting room and the members read and discussed papers of a mathematical nature. Of the group it was said, "of course we were much ridiculed by the Dons; and not being put down, it was darkly

35 Babbage, C. *Passages*, op. cit., p. 27.

36 The publications of the early scientific societies cover many subjects, including some early industrial management concepts. See Chapter VIII.

37 Babbage, C. *Passages*, op. cit., p. 29.
hinted that we were young infidels, and that no good would come of us." The group was said to be in favor of "The Principles of D-ism in opposition to the D-otage of the University." The Memoirs of the Analytical Society were published in 1813 by Babbage and Herschel, with the "hopes of promoting their favorite science." The Preface to these Memoirs shows that these two young men had a good knowledge of the history of calculus and a sound understanding of the importance of proper symbols in analytical work. They noted, "That man would render a most invaluable service to science, who would undertake the labor of reducing into a reasonable compass the whole essential part of analysis, with its applications, curtailing its superfluous luxuriance, rejecting its artificial difficulties, and giving connection and utility to its scattered members." This improvement of analysis was to become one of Babbage's lifelong objectives.

**Philosophical Breakfast**

While at Cambridge, Babbage was also associated with a group of intellectual fellow students who, every Sunday morning after chapel,
had "philosophical breakfast" together. This group was one of Babbage's favorites. It probably consisted of Babbage, Herschel, Richard Jones, Edward Jacob, Alexander D'Arblay, George Peacock, Edward Ryan, John Musgrove, and T. Greenwood. On Sundays, from 9:00 o'clock until past noon, this group would discuss "all knowable and many unknowable things." These university companionships, for the most part, ripened into close and permanent friendship. Later, many of the members of this group were to become some of the most eminent men of their time.

**Graduation and Marriage**

Babbage had entered Trinity College in 1810, but apparently transferred to Peterhouse in his third year. It has been said that Babbage made this transfer because he was sure that his friends, Herschel and Peacock, would stand first and second in their class at

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42 Babbage, C. Passages; op. cit., p. 34.

Stephen, Leslie op. cit., p. 236.

43 Babbage, C. Passages, op. cit., p. 34.


45 Babbage, C. Passages, op. cit., p. 34.

46 Jones, op. cit., p. xxi.


Trinity and that he preferred to be first at Peterhouse instead of third at Trinity. This analysis is difficult to understand, however, for Herschel was a year ahead of Babbage and graduated in 1813; Babbage graduated in 1814. Although Babbage did abandon all honors, he came out as Captain of the Poll.

Both Herschel and Babbage continued their studies and received their M.A. Degrees in 1816 and 1817 respectively.

Probably around 1815 Babbage married Georgiana Whitmore and began to raise a family in the house he purchased at #5 Devonshire Street, Portland Place, London. Since Babbage never mentioned his

49 Loc. cit.
A. M. C. op. cit., p. 304.

50 Stephen, Leslie op. cit., p. 263.

Herschel, op. cit., p. 120.

51 A. M. C. op. cit., p. 304.

52 Annual Register op. cit., p. 159.

The Athenaeum, op. cit., p. 564.

53 A. M. C. op. cit., p. 304.

Stephen, op. cit., p. 236.

54 The above conclusion is deduced from the following facts: Babbage's wife's death notice gives her first name as Georgiana (Ref. The Times, London: No. 13, 326, Wednesday, September 5, 1827); Babbage's brother-in-law's last name was Whitmore (Ref. Babbage, C. Passages, op. cit., p. 52); Babbage's second son's middle name was likewise Whitmore (Ref. The Times, London: No. 13, 342, Friday, July 27, 1827); Babbage's oldest son was born about 1815 (Ref. Babbage, C. Passages, op. cit., p. 207).

55 A. M. C. op. cit., p. 304.
marriage or wife in any of his writings, and neither do any of the sketches of his life, little is known about her or the influence she may have had on him.

Introduction of Modern Calculus into England

In order to encourage the English mathematicians to change their calculus notations to the superior ones of Leibnitz, Babbage began, in 1812, to translate the excellent French work of S. F. Lacroix on Differential and Integral Calculus. He only finished the translation of the Differential Calculus portion of the book, however, and later George Peacock and John Herschel, friends and fellow members of the Analytical Society, translated the remainder on Integral Calculus. The combined translation was published in 1816 as the joint work of the three men.

It had been the intention of these men to follow this book immediately with a set of example problems, but, due to various changes

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55 Cont.


57 Ibid., p. iiii.

58 Loc. cit.

Babbage, C. op. cit., p. 39.
of plans and other interests, this was not done until 1820. During their undergraduate years at Cambridge these three men—Babbage, Herschel, and Peacock—had made a compact to "do their best to leave the world wiser than they had found it." By their translation of Lacroix and the publication of the examples, they had already accomplished this. These two books helped successfully to introduce modern calculus into England. All three men, however, were headed for still greater accomplishments. As for their introduction of modern calculus into England, it was said, "in a very few years, the change was completely established; and at last the English cultivators of mathematical science, untrammelled by a limited and imperfect system of signs, entered on equal terms into competition with their continental rivals."

Early Contributions to Scientific Journals

In 1815 Babbage made the first of many contributions to


60 Stephen op. cit., p. 263.

61 A. M. C. op. cit., p. 304.

The Athenaeum, op. cit., p. 564.

scientific journals with his paper entitled, "An Essay Towards the
Calculus of Functions." This was followed by two more papers in
1816, four in 1817, two in 1819, and three in 1820.


65 Babbage, Charles "Observations on the Analogy which subsists between the Calculus of Functions and other branches of Analysis." Philosophical Transactions of the Royal Society of London, 1817, pp. 197-216.


All these papers, like the 1816 translation of Lacroix and the examples of 1820, were mathematical contributions. Some were of a very limited application while others "helped to found a new and yet unexplored branch of analysis" in mathematics. 68

**Election to the Royal Societies**

In 1816 the Royal Society of London, the most renowned scientific society of England, elected Babbage a member at age 24. 69 Four years later, in 1820, Babbage was elected to the Royal Society of Edinburgh. 70 Within a few years Babbage was to be one of the leading critics of the Royal Society of London and to eventually help improve its scientific aspects. 71

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67 Cont.


68 A. M. C. op. cit., p. 304.

69 Ibid.

70 Buxton, op. cit., p. 45.


Aspirations to Professorships

In 1816 Babbage aspired to the Professorship of Mathematics at the East India College at Haileybury. Although recommended by the noted mathematicians, Messrs. Ivory and Playfair, Babbage did not receive the appointment. This was the first of many appointments he was to seek and not receive. The second occasion was in 1819 when the Professorship of Mathematics at Edinburgh became vacant. Babbage immediately became a candidate and received testimony of his fitness from other famous mathematicians, Messrs. Lacroix, Boit, and Laplace. These recommendations were useless, however, for "not being a Scot" Babbage's application was rejected.

Astronomical Society

One of the scientific societies which Babbage helped establish was the Astronomical Society of London. Such a society had been contemplated by others, but it took the same trio of Babbage, Herschel, and Peacock to bring it into actual existence. On January 12, 1820, these three joined William Pearson, Arthur Baily, Francis Baily, Thomas Colby, Henry Colebrook, Olinthus G. Gregory, Stephen Groombridge, Patrick Kelly, Daniel Moore, James South, Charles Stokes, and Peter Salwinski in the first official meeting of

73 Ibid., p. 474.
the Astronomical Society of London. Babbage was one of the first Honorary Secretaries of this Society and later served as vice-president, foreign secretary, and member of the council. He also joined with other members of this society in revising the Nautical Almanac.

Some members of the dominant Royal Society of London, including its president, Sir Joseph Banks, strenuously opposed the formation of this new society. In spite of this opposition of the old order, the new society prospered. It still exists today as the world renowned Royal Astronomical Society.

For the part Babbage played in founding the Astronomical Society, Sir Joseph Banks later refused to recommend him for a position on the Board of Longitude. Without this support Babbage did not gain this position for which he should have been well qualified.

Travels Abroad

In 1821 Babbage traveled abroad with John Herschel. Besides

75 Loc. cit.
76 A. M. C. op. cit., p. 304.
77 Babbage, C. Passages, op. cit., p. 474.
78 Lyons, Sir Henry op. cit., pp. 216 f.
79 Lyons, Sir Henry op. cit., p. 229.
80 Babbage, C. Passages, op. cit., p. 474.
mountain climbing, these two visited the most outstanding French mathematicians of the time: Laplace, Poisson, Fourier, Bolt, Prony, and others. John Herschel's previous acquaintance with these men, through his internationally famous father, undoubtedly helped Babbage make their acquaintance.

Mechanical Calculation of Mathematical Tables

While at the University of Cambridge, Babbage had conceived an idea which was later to bring him his widest recognition and greatest disappointments. The idea was to construct machinery which would calculate and print various mathematical tables, using the mathematical method of differences as the means of computation.

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83 Babbage, C. Passages, op. cit., pp. 41 ff.

The principle in developing mathematical tables using the method of difference is demonstrated in the following tabulation:

<table>
<thead>
<tr>
<th>Number</th>
<th>Square of Number</th>
<th>Difference Between Squared Numbers</th>
<th>Difference Between Preceding Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>
Although conceived in 1812 or 1813, the idea lay dormant for some years.

Babbage's various reports on how this idea of mechanical calculation was reborn do not all agree. One relates that it was about 1820 or 1821 that he and John Herschel were checking some computations for the Astronomical Society when "After a time many discrepancies occurred, and at one time these discordances were so numerous that I, [Babbage] exclaimed, 'I wish to God these calculations had been executed by steam,' to which he [J. Herschel] replied 'It is quite possible.'" Babbage sought the advice of Dr. Wollaston on making

<table>
<thead>
<tr>
<th>Number</th>
<th>Square of Number</th>
<th>Difference Between Squared Numbers</th>
<th>Difference Between Preceding Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>16</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>49</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

From the above tabulation it is seen that the second difference for any squared number is always a constant of two. Thus, a table of squares can be computed by increasing the preceding first difference by two and adding this to the preceding squared number. Many other tables, or parts of tables, can be computed by using up to five or six orders of differences.

84 Babbage, C. Passages, op. cit., p. 42.

such a machine and was encouraged by him to undertake its construction. By June, 1822, Babbage announced that he had constructed a model machine which could mechanically compute some formulae.

Although Babbage was not the first to attempt to construct machinery to calculate mathematical tables, he was the first to design a machine employing the mathematical method of differences and the automatic printing of results. Some of the previous constructors of calculating machines were Pascal (1642), Morland (1666), Leibnitz (1694), Lepine (1725), Gersten (1735), Pereire (1751), Viscount Mahon later Earl of Stanhope (1775 and 1777), Hahn (1779), Muller (1785), and Thomas de Colmar (1820).

At least two events probably influenced Babbage's thinking on constructing a calculating machine. In 1820 Thomas de Colmar had

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86 Babbage, C. Passages, op. cit., p. 42.
made a machine which would add rapidly in order to yield multiplication results. Babbage probably knew of this machine. Also, by 1821, Babbage had examined the famous French mathematical tables, Tables des Cadastre, and had studied their method of computation which was based on the mathematical method of difference routine. The development of these French tables had required many, many man hours of tedious computation and Babbage said, "The intolerable labor and fatiguing monotony of a continuous repetition of similar arithmetical calculations, first excited the desire, and afterwards suggested the idea of a machine which by the aid of gravity or any other moving power, should become a substitute for one of the lowest operations of human intellect." Babbage realized the importance of making a machine do its own printing in order to eliminate the human error of copying. Of this he said, "I have contrived a means by which the machines themselves shall take from several boxes containing type the numbers which they calculate, and place them side by side; thus becoming at the same time a substitute for the compositor and computer; by which means all error in copying as well as in printing is removed."

89 Booth, op. cit., p. 6.


92 Loc. cit.
Potential accuracy was one of the main virtues of Babbage's proposed system. Many mathematical, astronomical, and navigational tables were already published, but their usefulness was often limited by the great number of errors they contained. Some of those used at the time were known to contain as many as 500 errors.93

On June 11, 1822, Babbage announced,

I have been engaging during the last few months in the contrivance of machinery, which by the application of a moving force may calculate any tables that may be required... I have repeatedly constructed tables of squared and triangular numbers....

In the prosecution of this plan, I have contrived methods by which types shall be set up by machines in the order determined by the calculations and the arrangements are of such a nature that, if executed, there shall not exist the possibility of error in any printed copy of tables computed by this machine. Of several of these latter contrivances, I have made models; and from the experiments I have already made, I feel great confidence in the complete success of the plan I have proposed.94

Seeking Financial Assistance

Babbage had confidence in his ability to construct a machine which could calculate and print many important tables. To secure financial assistance for the undertaking Babbage, on July 3, 1822, published and advertised for sale in the newspapers, a 12-page public letter entitled, "A Letter to Sir Humphry Davy, President of the

93 Loc. cit.

Royal Society, on the Application of Machinery to the Purpose of Calculating and Printing Mathematical Tables."\(^95\)

The letter discussed the need, advantages, and almost unlimited possibilities of this calculating machine. Babbage stated his proposition regarding the undertaking as follows,

I have made many experiments and several models; the results of these leave me no reason to doubt of success, which is still further confirmed by a working model that is just finished.

Whether I shall construct a larger engine of this kind, and bring to perfection the others I have described, will in a great measure depend on the nature of encouragement I may receive.

...I have now arrived at a point where success is no longer doubtful. It must, however, be attained at a very considerable expense, which would not probably be replaced, by the works it might produce, for a long period of time, and which is an undertaking I shall feel unwilling to commence...\(^96\)

Thus, Babbage presented his proposition of constructing a calculating machine to the public. He had worked out on paper and in models means of making many calculations by machinery. He had no reason to doubt the success of such a machine. It would take time to construct, and if he were to undertake the venture, he needed financial assistance. This venture of constructing machinery to calculate and present mathematical tables was an undertaking which

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\(^96\) Loc. cit.
was to predominantly influence Babbage during the remainder of his lifetime.

**Characteristics of Babbage During Early Years**

Some characteristics of Babbage were already becoming apparent. He was willing to champion causes; as the improvement of English mathematics indicated. He did not always complete what he started; the translation of Lagrange might never have been published if Peacock and Herschel had not finished the translation. He loved recreation and diversion; some of his favorites at Cambridge were chess, whist and boating. He let other interests interfere with his work; boating escapades sometimes took five or six days from Cambridge classes. He was an organizer and instigator of organized groups; the Analytical Society and the Astronomical Society were examples. He did not concentrate his energies on one thing, but had a diversity of interests and associates; of Cambridge he said, "I lived probably in a greater variety of sets than any of my young companions." He openly sought support and recognition for his projects; the published letter to Sir Humphry Davy was full of confidence in his own powers. He often sought honors for which others did not judge him qualified; the two professorships he desired were examples. He considered himself to be

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98 *Loc. cit.*
99 Babbage, C. *Passages*, op. cit., p. 34.
"tormented by great shyness," but others considered him to be characterized by conspicuous vigor.

Chapter Summary

Charles Babbage was born December 26, 1792, in Devonshire, England; the son of Benjamin Babbage, a wealthy banker.

Although Charles Babbage was sometimes in poor health as a boy, he was well educated at various English schools. At an early age he showed an interest in mathematics and was fairly accomplished in this field when he entered Cambridge in 1810.

Little is known of Babbage's studies at Cambridge, but while there he did come under the influence of Smithson Tennant and Dr. William Hyde Wollaston. He also became a very close friend of John Herschel, the only son of the famous astronomer, William Herschel, and one who was destined to become England's leading scientist in his day. The instructors at Cambridge, especially in mathematics, were not too progressive and as a result Babbage studied primarily on his own, reading many of the published papers of various European scientific societies.

Babbage joined with other promising Cambridge students and formed the Analytical Society to promote the science of mathematical analysis. In 1813 Babbage joined John Herschel in publishing the Memoirs of this society.

100 Ibid., p. 35.
101 A. S. op. cit., p. 103.
At Sunday morning philosophical breakfasts Babbage, John Herschel, Richard Jones, Edward Jacob, Alexander D'Arblay, George Peacock, Edward Ryan, John Musgrove, and T. Greenwood discussed many subjects of interest, knowable and unknowable. Many of these men were later to be among the most prominent in England.

Babbage graduated from Peterhouse, Cambridge, in 1814 and received his M.A. there in 1817. Meanwhile, around 1815 he married Georgiana Whitmore and they started raising their family at Portland Place, London.

Babbage began, and John Herschel and George Peacock finished, the translation of Lacroix's *Differential and Integral Calculus*. The publication of this work in 1816, plus the examples they issued in 1820, successfully brought about the introduction of modern calculus into England.

From 1815 through 1820 Babbage published eleven mathematical papers. In 1816 he was elected to the Royal Society of London and in 1820 to the Royal Society of Edinburgh. In 1816 and 1819 he tried for professorships in mathematics but failed to receive the appointments.

In 1820 Babbage, Herschel, and Peacock founded, in spite of strong opposition from more conservative scientists, the Astronomical Society of London. This society still exists today as the world renowned Royal Astronomical Society.

In 1821 Babbage traveled abroad with John Herschel and visited many of the famous French mathematicians of the day. About 1820
or 1821 Babbage started experimenting on the possibilities of constructing a machine which could automatically compute and print mathematical tables. By June, 1822, he was able to announce that he was confident he could construct such a machine which would thus advance the cause of science and become a substitute for the laborious and lowly tasks of computing tables manually. This was to be an expensive undertaking, but with the assistance of friends and favorable publicity Babbage, in 1823, received financial assistance from the British Government. This venture of constructing machinery to calculate and present mathematical tables was an undertaking which was to greatly influence Babbage during much of his lifetime.

The following were some of the characteristics of Babbage during his first thirty years. He was a champion of causes but frequently did not complete worthy projects which he had started. He had a wide variety of interests and notable associates and frequently led in forming organized societies. He openly sought recognition and support for his projects and sometimes sought honors for which others did not deem him qualified. Nothing in these first thirty years indicated an interest in manufacturing or management but he had established a sound basis of scientific analysis.
CHAPTER III

YEARS OF ACHIEVEMENT AND QUALIFIED SUCCESS

Introduction

Charles Babbage was now (1823) thirty years of age. As the son of a wealthy family he had been well educated and had shown a high degree of accomplishment in mathematics. His circle of friends now included some of the most promising young men of the time, as well as many eminent men of science in London and Paris.

Although Babbage was a person of varied interests, he recently had been concentrating on constructing a machine to calculate and print mathematical tables. He had formulated its principles on paper and had constructed models of some of its parts. He had no reason to doubt its success. The construction of such a machine would take much time; but, if he were to undertake the adventure, he needed financial assistance.

Promoting Support for the Calculating Machine

In the public letter to Sir Humphry Davy, Babbage had presented his idea of constructing a calculating machine and the need for financial assistance. Since none was immediately forthcoming, Babbage gave his project further publicity.

The Edinburgh Philosophical Journal of August, 1822, published a letter from Babbage entitled, "On Machinery for Calculating and Printing Mathematical Tables." In this letter Babbage indicated that a working model of the type-setting mechanism was recently constructed. At the conclusion of this letter, David Brewster, the editor and a friend of Babbage's, championed Babbage's cause. He expressed "hope that the British Government, or some other institution which it so liberally supports, will afford Mr. Babbage the means of constructing a large engine."3

Again in November, 1822, Babbage wrote to David Brewster, "On the Theoretical Principles of Machinery for Calculating Tables."4 Besides still seeking support for his project, Babbage concluded with the following prediction which shows how true his foresight could be:

I will yet venture to predict, that a time will arrive, when the accumulating labour which arises from the arithmetical applications of mathematical formulae, acting as a constantly retarding force, shall ultimately impede the useful progress of science, unless this or some equivalent method is devised for relieving it from the overwhelming incumbrance of numerical detail.5


3 Ibid., p. 281


5 Ibid., p. 128.
The next month, December, 1822, Babbage again called attention to the potentialities of mechanical computations in his report, "Observations on the Application of Machinery to the Computation of Mathematical Tables."  

Securing government support for a non-profit, scientific undertaking was not a new idea. The king, for example, had for many years financed the astronomical researches of the noted British astronomer, William Herschel. Babbage was a favorite of William Herschel and a very close friend of his only son, John Herschel. The king's support of William Herschel probably encouraged Babbage to seek backing for his project.

**Government Support**

By April, 1823, the Lords of the Treasury began to show some interest in Babbage's idea. This interest undoubtedly resulted from Babbage's promotions and the influence of his supporters.

The Lords of the Treasury sought "the opinion of the Royal Society on the merits and utility of the invention" and on

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9 Babbage, C. *Passages*, op. cit., p. 69.

10 Loc. cit.
May 1, 1823, received a favorable report from them. To complete the arrangements, Babbage visited the Chancellor of the Exchequer, Mr. Robinson, and received £1,500 pounds toward the construction of the calculating machine. No minutes were kept of this meeting, which years later was the source of much confusion and misunderstanding as to what responsibilities and obligations the government had or had not assumed.

Actual construction of the calculating machine began toward the end of 1823 in the workshop of Mr. Clement, at 21 Prospect Place, Lambeth. Here it continued uninterruptedly for four years. From the means of calculation used, the mathematical method of differences, the machine became known as the Difference Engine.

11 Loc. cit.
12 Ibid., p. 69.
13 Ibid., p. 73.
14 Ibid., p. 71.
17 There are many descriptions of the Difference Engine. Some of the best are as follows: The Edinburgh Review. LIX, No. 120, July, 1834, pp. 263-327.
During these four years that Clement and his men worked on the Difference Engine, Babbage no doubt spent much time in supervising it and working out details of its operations. He did not, however, devote all his time to the Difference Engine, as one is sometimes led to believe from his writings. The evidence showed that he still pursued many other interests.

Scriptores Optici

In 1823 Babbage edited Scriptores Optici, or A Collection of Tracts Relating to Optics. This work had been started some thirty years earlier by Baron Maseres and "its existence forgotten for some time." When later reminded of this work, the Baron, in his ninetieth year, requested Babbage's assistance in completing its publication. Although Babbage contributed the Preface and was listed as the editor, for some unknown reason, he never referred to it in his list of writings.

17 Cont.


18 Babbage, O. Passages, op. cit., p. 105.

19 Babbage, Charles Scriptores Optici; or, A Collection of Tracts Relating to Optics. London: R. Wilks, 1823.

20 Ibid., Preface.

21 Loc. cit.

22 Babbage, O. Passages, op. cit., pp. 493-496.
Papers and Travels of 1824

In 1824 Babbage contributed a small mathematical paper, "On the Determination of the General Term of a New Class of Infinite Series," and a letter to Brewster's Edinburgh Journal of Science, concerning "Observations on the Measurement of Heights by the Barometer." This latter subject was of semi-popular interest at the time. Babbage probably carried out some of his own suggestions on this subject when, later that year, he again traveled abroad with John Herschel and made barometric determinations of the height of Mount Etna.

Gold Medal

The first gold medal of the Astronomical Society was presented to Charles Babbage, in 1824, for his work on developing a machine to calculate astronomical tables. Although the machine was not yet completed, Mr. Henry T. Colebrooke, in making the presentation noted, "Through Mr. Babbage's invention, the most irksome portion of the astronomers' task is alleviated, and a fresh impulse is given to


astronomical research." For the rest of his life, Babbage "was very proud of being the recipient of the first medal ever awarded by the Society." Since Babbage later quite openly sought other gold medals, one wonders if he had not sought this one from his friends.

Life Assurance Societies

In 1824 Babbage "was invited to take the entire organization and management" of the Protector Life (No. 1), an office for the assurance of lives then about to be established. For this he was to receive an annual salary of 1,500 pounds plus any outside income he might earn from private practice as an Actuary.


Sheepshanks, Richard A Letter to the Board of Visitors of the Greenwich Royal Observatory in Reply to the Calumnies of Mr. Babbage at their Meeting in June 1853, and in his Book Entitled, The Exposition of 1851. London: G. Barclay, 1854, p. 44.

29 Babbage, C. Passages, op. cit., p. 474.


31 Babbage, C. Passages, op. cit., p. 475.
Babbage accepted the offer and spent three months in preparing for the opening and studying the operations of other similar assurance societies.\textsuperscript{32} He noted errors in the mortality tables then in use and, therefore, computed one of his own from available data on deaths which had actually been occurring.\textsuperscript{33} He advocated that further statistics on actual mortality rates should be compiled, made public, and used by the life assurance societies.\textsuperscript{34}

With the date of opening established, something unexplained occurred and those concerned with the new assurance society, with which Babbage was connected, gave up the venture.\textsuperscript{35} During the next year another life assurance society invited Babbage to take over its management, but he declined.\textsuperscript{36}

The information Babbage had collected and computed on life assurance induced him to publish, in 1826, a small volume entitled, A Comparative View of the Various Institutions for the Assurance of Lives.\textsuperscript{37} In 1827 this book was translated into German and its

\begin{itemize}
\item \textsuperscript{32} \textit{Loc. cit.}
\item Walford, \textit{op. cit.}, p. 11.
\item \textsuperscript{33} \textit{Ibid.}, pp. 10-11.
\item \textsuperscript{34} \textit{Ibid.}, p. 10.
\item \textsuperscript{35} Babbage, C. \textit{Passages, op. cit.}, p. 475.
\item \textsuperscript{36} \textit{Ibid.}, p. 476.
\item \textsuperscript{37} Babbage, C. \textit{A Comparative View of the Various Institutions for the Assurance of Lives}. London: J. Mawman, 1826.
\end{itemize}
information used to establish "the best known German Life Office—the Gotha Life Assu. Bank." It is to Babbage's credit to note that the experience of the German institution agreed very nearly with the table constructed by Babbage.

Today this book of Babbage's is regarded as "An exceedingly interesting exposition of life assurance theory and practice in 1826 by an informed, fearlessly critical reviewer. A classic."  

Progress of the Difference Engine

A year after the construction of the Difference Engine was begun it seemed to be progressing nicely. After discussing its progress with Babbage, David Brewster commented as follows:

The extraordinary machine invented by Mr. Babbage, and now constructing under the patronage of Government has excited so much interest in every part of Europe, that we have been anxious to gratify the curiosity of our readers by any details respecting the nature and progress of the machine... [it] is extremely simple in its construction and all its functions are performed with a very slight mechanical power."

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37 Cont.

Babbage, C. Passages, op. cit., p. 176.

38 Walford, op. cit., p. 11.

39 Ibid., pp. 11-12.


The machine now constructing by Mr. Babbage is intended to compute tables with four orders of differences, and there will be attached to it an apparatus for punching upon copper, or impressing upon some other soft substances the figures which it computes.\(^2\)

Equations "can be computed and presented by machinery of no very great complication, and...it is not necessary (after setting the machine at the beginning) to do anything more than turn the handle of the instrument."\(^3\)

Babbage's dream seemed to be coming true.

**Magnetic and Electrical Experiments**

About 1820 Oersted had discovered a relationship between electricity and magnetism.\(^4\) Immediately following this, many scientists conducted further experiments on the subject. By the later part of 1824 and early 1825, Babbage and John Herschel extended the important experiments of the French scientist, Mr. Arago, and conducted a series of delicate experiments which endeavored to determine the effect of magnetism on various types of metals. Their conclusions were published before the Royal Society in their joint article, "Account of the Repetition of Mr. Arago's Experiments on Magnetism Manifested by Various Substances during Rotation."\(^5\)

\(^{1}\) Oersted, op. cit., p. 124.

\(^{2}\) Loc. cit.

\(^{3}\) Loc. cit.

\(^{4}\) Weld, op. cit., p. 314.

From these and other earlier experiments, Babbage concluded that time is requisite, "both for the development and the loss of magnetism, and that different metals differ, in respect not only to the time they require, but of the intensity of force ultimately producible in them." These experiments were given recognition in at least three articles by David Brewster, the last of which was obviously to placate Babbage who felt his experiments had not received sufficient recognition.

Babbage made further experiments similar to the above and, in 1826, presented his findings to the Royal Society in his paper "On Electric and Magnetic Rotation." The conclusions, however, were apparently not favorably received for Babbage later wrote, "they met with so little acceptance in England that I had ceased to contend for them against more popular doctrines."
Unfortunately for Babbage and the advancement of science, the things about magnetism which he had noted were largely ignored for over 50 years. It wasn't until 1885 that Sir James Ewing studied similar characteristics and, with advanced techniques of measurement, furthered Babbage's earlier conclusions and proved that different metals have different hysteresis curves and do vary as to time and magnetic force producible in them.  

Although the experiments of Messrs. Babbage and Herschel did not accomplish the advancement of science that they might have, they did result in the invention of "the 'astatic' or neutralized magnetic needle—a local instrument which was no sooner available than it was found to be indispensable."  

The only other publication by Babbage, in 1825, was a paper presented to the Astronomical Society, "On a New Zenith Micrometer."  

Year 1826  
The year 1826 was a very productive one. In addition to the previously noted book, A Comparative View of the Various Institutions for the Assurance of Lives, and the article "On Electric and Magnetic  


Rotation,\textsuperscript{53} Babbage contributed articles "On the Diving Bell,\textsuperscript{54}
"On a Method of Expressing by Signs the Action of Machinery,\textsuperscript{55}
"On the Influence of Signs on Mathematical Reasoning,"\textsuperscript{56} "On Notation,
"On Porisms,"\textsuperscript{58} and the book A Table of Logarithms of the
Natural Numbers, from 1 to 108,000.\textsuperscript{59}

Diving Bell

The Encyclopedia Metropolitana article "On the Diving Bell"
probably resulted from some experiments Babbage had made at Plymouth
in 1818,\textsuperscript{60} as well as his close friendship with the famous civil

\textsuperscript{53} Cf. ante.

\textsuperscript{54} Babbage, Charles "On the Diving Bell." Encyclopedia
Metropolitana, 1826.

\textsuperscript{55} Babbage, Charles "On a Method of Expressing by Signs the
Action of Machinery." Philosophical Transactions of the Royal

\textsuperscript{56} Babbage, Charles "On the Influence of Signs on Mathematical
Reasoning." Transactions of the Cambridge Philosophical Society, II,
1826, pp. 218 ff.

\textsuperscript{57} Babbage, Charles "On Notation." Edinburgh Encyclopedia,
Edinburgh: Blackwood, 1830, XV, pp. 394-399.

\textsuperscript{58} Babbage, Charles "On Porisms." Edinburgh Encyclopedia,

\textsuperscript{59} Babbage, Charles A Table of Logarithms of the Natural Numbers,
from 1 to 108,000. London: J. Mawman, 1827.

\textsuperscript{60} Babbage, C. Passages, op. cit., pp. 208-212.
engineers, Messrs. Marc I. and Isabard K. Brunel. Babbage enjoyed following the work of this famous father-son team as they built the Thames Tunnel, bridges, steamships, and railroads.

Expressing by Signs the Action of Machinery

With the article "On a Method of Expressing by Signs the Action of Machinery" Babbage had expected to receive the first Royal Medal given annually by the Royal Society. Two years earlier he had received the first gold medal bestowed by the Astronomical Society and "felt, therefore, that the first Royal medal might fairly become an object of ambition, whatever might be the worth of subsequent ones." The Royal Society medals were to be awarded "for the most important discoveries or series of investigations, completed and made known to the Royal Society in the year preceding the day of the award." Babbage was sure his paper would secure one of the medals for him, for he had no doubts that his paper was the best contribution


64 Babbage, C. Passages, op. cit., p. 145.

65 Ibid., p. 144.
of the year. He thought the ideas in his paper enabled one to carry through thoughts of "the most entangled and perplexed which probably ever occupied human mind." His later article "On the Influence of Signs in Mathematical Reasoning" was undoubtedly to call further attention to this previous paper.

When, in November, 1826, the medals were awarded to others, for work done prior to that year, Babbage felt that he had been done a great injustice and vigorously protested to the Council of the Royal Society. A few years later in his book, *Decline of Science in England*, he bitterly wrote of this injustice done him.

Babbage was certainly not humble in his opinion of his own accomplishments. He seemed not only continually to seek recognition, but frequently to fight for it.

Throughout the rest of his life, Babbage frequently promoted his idea of using signs to express the action of machinery for "he had little doubt that it would be adopted as the ordinary language for all machinery; because by its means, even the most complicated mechanism could be easily understood." In spite of Babbage's

66 Ibid., p. 146.


68 Sheepsbanks, *op. cit.*, p. 45.


promotions it is not known to have been adopted widely in England. However abroad "It was, almost immediately after its publication, adopted as the topic of lectures, in an institution on the Continent for the instruction of Civil Engineers."72

Years later Babbage was "fond of performing the following feat to exhibit his powers. He would request his visitor to select one from the hundreds of drawings before him, executed perhaps ten years previously. Turning his back on the drawings, he desired his visitor to place his finger on any part of it. He then asked him a few questions as to the letters and symbols on or near that part, whether they were upright or sloping, large or small, Arabic or Roman, etc., and he then, without any apparent exercise of thought and without any hesitation, described the part, its function, position, in relation to the whole."73

Table of Logarithms

The Table of Logarithms of the Natural Numbers, from 1 to 108,000 was published by Babbage early in 182674 for "the use of the

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72 "Babbage's Calculating Engine." The Edinburgh Review, LIX, No. 120, July, 1834, p. 318.


74 Babbage, C. Table of Logarithms, op. cit., 1827.
These tables were the best of their time and were reprinted at various times due to their high degree of accuracy and useful method of presentation. In publishing the tables Babbage did an exceedingly good job in accomplishing his following two major objectives: "correctness, and the facility with which they can be used by computers." 

To achieve correctness Babbage compared his tables with eight other known log tables. To make the tables clear and easy to use he studied many other tables and came to the following conclusions:

First, the clearness or facility of reading, does not depend on the size of the type alone, but on the proportion of the type to the interval between the lines.

Secondly, figures of the same or nearly the same height, are preferable to those in which some of the digits rise above and others fall below the line.

Thirdly, the lines dividing the vertical columns should not be placed in the middle of space between the columns, but should be nearer the preceding column.

Fourth, when some parts of the table are to be separated from the rest more decisively than by ordinary lines, a single dark line is much more conspicuous than two fainter lines adjacent to each other; and, if necessary, for further distinction, another, and much darker line, may be employed with success.

Fifthly, those figures which are first sought on entering a table, ought to be so distinguished, either by position

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76 Babbage, C. Table of Logarithms, op. cit., p. v.

or magnitude, as to strike the eye.

[The sixth and seventh apply to log tables specifically].

Eighth, whenever additional information can be communicated in a table without increasing bulk, or adding much to its expense, it ought always to be given. Unless it is of such a nature as to distract the attention too much from the part most frequently used.

Ninth, the different tables in a volume ought to be distinguished from each other by the art of the printer in such a manner that any one can, from its peculiarity, be readily distinguished in turning the pages over rapidly.

Tenth, the impression of the figures on one page is reversed on the opposite.

Eleventh, the transparency of the paper permits the figures on the reverse side to appear through.

Twelfth, colored paper is more favorable to distinctness than white. 78 & 79

Relative to the last conclusion, Babbage added,

Almost all those whom I consulted agreed with me in giving the preference to the colored paper, but the particular tint was not so unanimously fixed on. Yellow appeared to have the preference... It is not probable that color first selected should be found the best; we must wait the result of time and experience to determine this point. It may, perhaps, be found that the different eyes require different colors; and that it is not improbable that a tint which is least fatiguing to the eye when used by candle light, may not be the best adopted to calculations by daylight. 80

78 Babbage, C. Table of Logarithms, op. cit., pp. vii-xi.


80 Babbage, C. Table of Logarithms, op. cit., p. xi.
The above quotations show the exactness and completeness to which Babbage could carry analysis. An examination of these logarithmic tables showed that he applied the above principles, including printing the tables on a greenish yellow paper.

Paris and Secretaryship of the Royal Society

Other events of 1826 included at least one trip to Paris with his wife, and an unsuccessful attempt to be appointed junior secretary of the Royal Society.

Sir Humphry Davy was President of the Royal Society this year and Babbage's friend, John Herschel, was senior secretary. Babbage had understood that he was promised the junior Secretaryship; but, when Davy claimed the right to nominate whom he wished, Babbage was extremely aggravated with Davy and the council. Writing of this years later he said, "The President, as president, has no such right; and even if he had possessed it, he had promised Mr. Herschel that I should be his colleague. There were upright and eminent men on that council; yet no one of them had the moral courage to oppose the President's dictation, or afterwards to set it aside on the grounds of its irregularity."

82 Babbage, C. Passages, op. cit., p. 186.
83 Loc. cit.
84 Sheepsbanks, op. cit., pp. 40 ff.
85 Babbage, C. Passages, op. cit., p. 186.
This incident shows Babbage's extreme self esteem, lack of tact, and impracticality. In studying his life, it appears that these qualities got him into trouble more than once. He might have accomplished more if he had learned humility, tact, and compromise.

Seeking a Professorship

In 1826 Babbage made an unsuccessful attempt to be appointed Lucasian professor of mathematics at Cambridge. This professorship was mostly honorary as it was the "chair" occupied years earlier by Newton.

The following quotes from William Whewell's published letters tells most of the story of Babbage's seeking the Lucasian Professorship.

October 18, 1826 [in a letter to Richard Jones]. Babbage is making application, and has written to people here on the subject. He has no chance, whatever, and it is mere extravagance, at least, as appears to me, his taking up the thing. I do undoubtedly believe that he would be a good professor now but it is too much to expect that our Heads should understand not only his merits, but the varying shape of them as time and circumstance may have modified it.

November 18, 1826 [in a letter to Earl of Rosse]. I wish Babbage had a chance. He would be an admirable person, and so would Airy, who is also a candidate.

December 10, 1826 [in a letter to Richard Jones]. Do you know that we have settled the Lucasian Professorship by giving it to Airy? Babbage came here to canvass, and is

85 Ibid., p. 31.
86 Todhunter, op. cit., p. 74.
87 Ibid., p. 76.
now here. He has effected a complete conquest of your
Master's good graces and is staying at Gains Lodge.
Herschel has also been here to support him, but all in
vain.88

There had been a third candidate, Dr. French, but he withdrew
when Babbage threatened to start legal proceedings against him.89
Babbage and French may have destroyed each other's chances and thus
enabled Airy to be elected.90

Although Babbage wrote of some of his unsuccessful ventures,
he never mentioned this one. Perhaps this was because two years
later, in 1828, the Lucasian Professorship was again vacant and this
time he was appointed to fill the chair.

Year 1827

At thirty-four years of age, Charles Babbage was doing fairly
well, in spite of some setbacks. His Difference Engine seemed to be
progressing satisfactorily. He had published four books and numerous
articles. He was internationally known, not only by scientists but
by many "men of the street," for his Difference Engine had received
wide publicity "due to its being an object of interest to the ingeniun
and of curiosity to the uningenious of both continents."91

88 Ibid., p. 80.
89 Airy, op. cit., p. 70.
90 Macfarlane, Alexander Lectures on Ten British Physicists.
No. 20, p. 110. Mansfield Merriam and Robert S. Woodward, editors,
91 "Charles Babbage, Philosopher." Van Nostrand's Electric
This year, 1827, Babbage gave testimony on savings banks before a Committee of the House of Commons and was on the Council of the Royal Society. He was also on a special committee of the Royal Society to "Consider the best means of limiting the members admitted to the Royal Society, as well as making suggestions on that subject that may seem to them conclusive to the welfare of the Society." The real purpose of this committee was to raise the scientific standards of the Society as Babbage, South, and others were advocating.

Tragedy

This same year, 1827, real tragedy began to strike. On July 26, Babbage's second oldest son, Charles Whitmore, died. On September 1, his wife, Georgiana, died at age 35. The next year, 1828, his father died. There may have been more deaths in the family, but Babbage supplied no specific information on the deaths.

By the end of 1828 Charles Babbage's immediate family consisted

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of his eldest son, Benjamin Herschel Babbage, his youngest son, Henry Prevost Babbage, his daughter, and his mother.

Travel Abroad

By October, 1827, after the death of his son and wife, Charles Babbage was in a very poor state of health and was "recommended by his medical advisors to travel to the continent." His close friend, John Herschel, abandoned his own pursuits and went to Ireland and then to the continent with Babbage "to aid time and change of scene in alleviating the affliction of his companion."

Prior to leaving for the continent, Babbage made several arrangements. First, for reasons unstated, he sold his house on Devonshire Street. Second, he left drawings for the construction of the Difference Engine. Third, to meet the expenses of construction,

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98 Ibid., p. 331.


101 Babbage, C. Passages, op. cit., p. 72.


105 Babbage, C. Passages, op. cit., p. 72.
he made arrangements for his banker to advance 1,000 pounds, as needed.

Italy

While abroad, Babbage spent much of his time in Italy. As always, he pursued his love of investigation. At Naples he not only observed the moderately active volcano, Vesuvius, but at his own personal risk, descended into one of its craters to observe the action of the molten lava. Also while in Italy, Babbage served, at the request of the Italian government, on a Commission investigating the hot springs at Ischia.

Always Babbage was equipped with his notebook in which he recorded many interesting observations. These were sometimes the basis for future articles, as in the case of the article, "Observations on the Temple of Serapis."

Visiting Foreign Workshops

Whenever opportunity presented itself, Babbage visited workshops

106 Loc. cit.
107 Ibid., p. 430.
108 Ibid., p. 214-222.
109 Ibid., pp. 222-223.
110 Ibid., pp. 372 ff.
in England and in foreign lands to observe their operations.\textsuperscript{112}

To gain initial acceptance among workmen he used various devices. One was to produce casually from his vest pocket an unusually fine, diamond cut, steel die.\textsuperscript{113} Another device was a clever but little known means of punching holes in glass.\textsuperscript{114}

Babbage was frequently well received and some of his visits to Italian factories provided material for his book, \textit{On the Economy of Machinery and Manufactures}.\textsuperscript{115}

Appointment as Lucasian Professor

It will be remembered that in 1826, Babbage had unsuccessfully sought appointment as Lucasian Professor at Cambridge. In 1828, while in Italy, Babbage did receive this appointment through the help of his friend, John Herschel.\textsuperscript{116} The following quotes from two letters by William Whewell tell the story:

\textbf{[Letter to Richard Jones, January 6, 1828]} We have another professorship vacant by Woodhouse's death. Airy will probably succeed him, and the vacant one will be the Lucasian, for which Babbage was a candidate. Some people here hope that Herschel will take it, which I doubt. I should rejoice to have Babbage, but I am not sure that he...would succeed, and not at all certain that he would now offer himself. He is in Naples and long to get at.

\textsuperscript{112} Babbage, C. \textit{Passages}, op. cit., pp. 374 ff.
\textsuperscript{113} \textit{Ibid.}, p. 373.
\textsuperscript{114} \textit{Ibid.}, pp. 377 ff.
\textsuperscript{115} \textit{Ibid.}, p. 375.
\textsuperscript{116} Babbage, C. \textit{On the Economy of Machinery and Manufactures}. London: Charles Knight, 1832.
\textsuperscript{117} Todhunter, \textit{op. cit.}, p. 89.
[Letter to John Herschel, March 6, 1828] I hope you will be glad to hear, as I am to tell you, that Babbage was today elected our Lucasian Professor. It was entirely in consequence of your letter, which I got yesterday, that I bestirred myself in the matter, for before that I did not consider myself sufficiently authorized to press his claims upon the electors. Peacock, Higman and I wrote a letter to each of them which was sent last night about eleven o'clock, and today at two o'clock the election took place. Nothing could be more distinguished than the mode of giving him the chair, for though at such a period one might have naturally supposed a large proportion of votes to be engaged, out of the 11 electors, only 2 voted for one other candidate, and one for a third. I hope Babbage will take the matter in the same spirit in which I am sure it was received here: for I am quite clear that the Heads elected him in a very cordial regard, for his talents and confidence in his good will to the office and its duties. I suppose you and some of his friends will write him immediately and inform him of what has been done. It was at first suggested that a difficulty would arise in consequence of the impossibility of his being admitted immediately, but it appears that the words of the deed require him to be admitted 'proximo opportuno tempore' which allows any reasonable latitude of interpretations. In what I had to say to the electors about the matter I referred them to their own interviews with him on the former occasion for information as to his intentions with regard to the manner of discharging his Lucasian functions.

I rejoice very much at the event of this business, for it is very honorable to him, and, as appears to me, to the electors, noting the ways to obtain the best professor for the University and to do justice to Babbage can be supposed to have influenced them; and having been obliged to act in some haste, and to take a responsibility which might have been disagreeable, if matters had turned out otherwise, I am very glad to find that, judging favorably of our Heads, and not despairing of the results, we have been led to that which, will, I hope be a source of satisfaction both to our new professor and to us. Yours very truly,

Upon receiving notice of the appointment Babbage said he planned to turn it down until he realized the "election could not have occurred unless some friends----had taken measures to promote it...and

118 Ibid., pp. 90-91.
it would be harsh to disappoint such friends, and reject such a compliment."\textsuperscript{119}

It is hard to believe that Babbage actually would have turned down this opportunity for he always sought such recognition and had worked hard for it two years earlier. The Lucasian Professorship was more honor than income, for it only paid 80 or 90 pounds annually.\textsuperscript{120} Babbage later regarded this professorship as "the only honor I ever received in my own country."\textsuperscript{121}

During the time Babbage was Lucasian Professor, from 1828 until he resigned it in 1839, he carried out very few professorial activities.\textsuperscript{122} Although Professor Airy, Babbage's predecessor as Lucasian Professor, had been the first Lucasian Professor to lecture in many years, Babbage did not lecture.\textsuperscript{123} Some suspected this was due to the lack of his ability to secure a class,\textsuperscript{124} and others said it was because "his mind was completely adsorbed with anxiety about the success and fame of his computing machine."\textsuperscript{125} However, the

\textsuperscript{120} Ibid., p. 34.
\textsuperscript{121} Ibid., p. 34.
\textsuperscript{122} Ibid., pp. 31-34.
\textsuperscript{123} Todhunter, op. cit., p. 80.
\textsuperscript{124} Macfarlane, op. cit., p. 74.
following quote from Babbage's arch-enemy, Richard Sheepshanks, probably provides the best explanation as to why he did not lecture.

Mr. Babbage never lectured at all, though he once proposed to lecture, and I believe I helped to stop him. He gravely proposed to lecture immediately after the Senate House examination, when there is no one in the University; and the bill of fare was to be composed of what he had written (about the Economy of Manufactures, I believe,) for the Encyclopaedia Metropolitana. This he was to read from the slip. I pointed out to him that it must be a mere Walls' lecture at that season; though I was not candid enough to add, that such lectures would not draw in the University, where no man would go to hear read, and perhaps badly read, what he can read himself in good print in a few weeks. I think, too, the subject did not belong to his Professorship. 126

The only duty Babbage is known to have performed as Lucasian Professor was to participate in the examination of candidates for special prizes at graduation. 127

Babbage's appointment as Lucasian Professor probably had an influence on his publishing The Economy of Machinery and Manufactures for he dedicated the book, "to the University of Cambridge,...as a tribute of respect and gratitude," 128 Furthermore, in the preface he stated, "It was my intention to have delivered the present work in the form of a course of lectures at Cambridge; an intention which I was subsequently induced to alter." 129

126 Sheepshanks, op. cit., p. 78.
127 Babbage, C. Passages, op. cit., pp. 31-33.
129 Ibid., p. vi.
Return to England

In 1828, Babbage returned to England from Italy via Germany in order to visit the great German savant, Alexander von Humboldt. This visit happened to coincide with an important meeting of German scientists to which Humboldt invited Babbage. Babbage was honored by this and reported the meetings in his article, "Account of the Great Congress of Philosophers at Berlin, on 18 September, 1828." Babbage's good friend and advisor, Dr. Wollaston, died soon after Babbage's return to England. Following this death, Babbage purchased Dr. Wollaston's house at One Dorset Street, Manchester Square, London and made this his home for the rest of his life.

130 Babbage, C. Passages, op. cit., p. 129.


132 Loc. cit.

133 Loc. cit.
Difference Engine Difficulties 135

When Babbage left for Italy in 1827, the expenses of the Difference Engine had amounted to £3,475 pounds (approximately $16,575). 136 This was more than twice the amount originally granted by the government and, in addition to the above, Babbage had advanced £1,000 pounds more while in Italy. 137

As it now appeared probable that the expense would much exceed what Mr. Babbage had originally anticipated, he thought it desirable to inform the government of that fact, and to procure a further grant. As a preliminary step, he wrote from Italy to his brother-in-law, Mr. Wolryche Whitmore, to request that he would see Lord Goderich upon the subject of the interview in July, 1823; but it is probable that he did not sufficiently inform Mr. Whitmore of all the circumstances of the case.

Mr. Whitmore, having some conversation with Lord Goderich on the subject, addressed a letter, dated on the 29th of February, 1828, to Mr. Babbage, who was then at Rome, stating,

'That interview was unsatisfactory; that Lord Goderich did not like to admit that there was any understanding at the time the £1,500 pounds was advanced, that more would be given by government.' 138

Thus started a series of differences of opinion and misunderstandings between Babbage and the government. These were to

135 The following details on the Difference Engine controversy may be too detailed for some, but they are given because they were a source of great controversy and if one is to pass judgment on Babbage he should be cognizant of these facts.

136 Babbage, C. Passages, op. cit., p. 72.

137 Loc. cit.

138 Loc. cit.
continue until they were unsatisfactorily settled in 1842, and the repercussions were to plague Babbage the rest of his life.

Financing the Difference Engine

With his return to England, Babbage again turned his attention to the Difference Engine. By December, 1828, he was able to say, "The work is now in a state of considerable forwardness, numerous and large drawings of it have been made, and much of the mechanism has been executed, and many workmen are occupied daily in its completion."\(^{140}\)

To secure more governmental financial assistance Babbage visited Lord Goderich, Chancellor of the Exchequer, without apparent success.\(^{141}\) He then addressed a statement to the Duke of Wellington, the Prime Minister, who in turn sought the advice of the Royal Society.\(^{142}\) On February 12, 1829, the Council of the Royal Society returned a favorable report from a special committee established to investigate Babbage's project. They stated they had "not the slightest hesitation in pronouncing their decision in the affirmative"\(^{143}\) and hoped "that while Mr. Babbage's mind is

\(^{139}\) Ibid., pp. 72-96.
\(^{140}\) Weld, op. cit., Chapter XI.
\(^{141}\) Ibid., op. cit., p. 375.
\(^{142}\) Babbage, C. Passages, op. cit., p. 73.
\(^{143}\) Ibid. "Mr. Babbage's Calculating Machine." The Times, London: No. 15,011, Friday, November, 16, 1832, p. 3.
intently occupied on an undertaking likely to do so much honor to this country, he may be relieved, as much as possible, from all other sources of anxiety.\textsuperscript{1h4}

Some of Babbage's closest friends and strongest supporters were on the Council of the Royal Society and on the special committee to investigate the Difference Engine. John Herschel was chairman of the special committee\textsuperscript{1h5} which reported in part as follows:

In the actual execution of the work, they find that Mr. Babbage has made a progress which, considering the very great difficulties to be overcome in an undertaking so novel, they regard as fully equaling any expectations that could reasonably have been performed; and that although several years have now elapsed since the first commencement, yet that when the necessity of constructing plans, sections, elevations and working drawings of every part; that of constructing, and in many cases inventing, tools and machinery, of great expense and complexity, (and in many instances of ingenious contrivances, and likely to prove useful for other purposes hereafter), for forming with the requisite precision parts of the apparatus dissimilar to any used in ordinary mechanical works; that of making any previous trials to ascertain the validity of proposed movements; and that of altering, improving and simplifying those already contrived and reduced to drawing; your committee are so far from being surprised at the time it has occupied to bring it to the present state that they feel more disposed to wonder it has been possible to accomplish so much.

\textsuperscript{\ldots} According to what the committee have been able to gather from Mr. Babbage's statements and their own observations, in supposing no unexpected cause of delay, they regard a further period of three years as probably sufficient for its completion.\textsuperscript{\ldots}\textsuperscript{\ldots} The actual work of the calculating part is in a great measure constructed, although not put together

\textsuperscript{1h4} Loc. cit.

\textsuperscript{1h5} Loc. cit.
...they regard as extremely judicious, although, of course, very expensive, Mr. Babbage's determination to admit of nothing but the very best and most finished work in every part.

In the printing part less progress has been made in actual execution than in calculating. The reason being the greater difficulty...for giving to the plate itself, the number and variety of movements which the forms adopted in printing tables call for in practice...taking the calculating and printing parts together, and regarding the tools and machinery already erected as available for the performance of all remains, the committee regard it as not improbable that three-fifths of the work may already be completed, but they cannot be expected to state this with any degree of certainty.

Construction Stopped

In consequence of this favorable report, the treasury, in April, 1829, directed a further payment be made to Mr. Babbage of 1,500 pounds, "to enable him to complete the machine by which such important benefit to success of science might be expected." Less than two weeks later, on May 9, 1829, work was stopped, presumably due to questions as to whether or not the bills presented by Mr. Clement were reasonable. Up to this time 6,628 pounds (approximately $33,140) had been expended on the construction of the Difference Engine, of which the government had committed itself for only 3,000 pounds.

146 Loc. cit.
147 Babbage, C. Passages, op. cit., p. 73.
149 Babbage, C. Passages, op. cit., p. 78.
Three days following the cessation of work, a group of Mr. Babbage's friends, influential in government and science, met with him and drew up a statement of "facts" regarding the circumstances of the construction of the Difference Engine. This statement concluded that Mr. Babbage's private fortune was not such as would justify his completing the Difference Engine without further and effectual assistance from the government and, if the government could not give further assistance, "they must regard Mr. Babbage... as no longer called on to proceed with an undertaking which might destroy his health and injure, if not ruin, his fortune."\(^{150}\)

Following this meeting Messrs. Whitmore and Herschel conveyed these sentiments to the Duke of Wellington.\(^{151}\)

**Support of Wellington**

The Duke of Wellington visited the workshops of Clement in November, 1829, in order to inspect the progress of construction of the Difference Engine.\(^{152}\) He suggested that the printing mechanism be separated from the calculating mechanism.\(^{153}\) Following the visit, 3,000 pounds more were granted to Babbage by the government.\(^{154}\)

\(^{150}\) [Ibid., p. 74.]

\(^{151}\) [Loc. cit.]

\(^{152}\) [Ibid., p. 75.]

\(^{153}\) [Loc. cit.]

\(^{154}\) [Loc. cit.]
More correspondence and meetings followed. There was concern as to what was the government's and what was Babbage's responsibility. Due to lack of funds and complications in getting his bills examined, Mr. Clement was now threatening to discharge some of the workmen engaged in constructing the Difference Engine.

New Workshops

At this time, Babbage wrote the treasury, "that since it is absolutely necessary to find additional room for the erection of the machine, it becomes a matter of serious consideration whether it would not contribute to the speedier completion of the machine and also to economy and expenditure to remove the works to the neighborhood of my own residence." Apparently Babbage and Clement still could not get along with one another.

More letters and contradictory statements came from the government. Finally, the government gave a total of 7,500 pounds in addition to their original 1,500 pounds. The government now said it would not pledge itself to complete the machine but "when the machine was completed, the government would be willing to

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155 Ibid., pp. 75 ff.
157 Loc. cit.
158 Sheepshanks, op. cit., p. 66.
159 Babbage, C. Passages, op. cit., p. 80.
attend to any claim of Mr. Babbage's to remuneration.\textsuperscript{160} Meanwhile, no work was being done on the machine. Construction was finally resumed, however, in March, 1830, and continued until April, 1833.

Babbage and his friends in the Royal Society had "anxieties\textsuperscript{161}" over the drawings and parts being exposed to destruction from fire and other disasters.\textsuperscript{162} Therefore, at an additional cost of several thousand pounds, the government constructed near Babbage's home a "fireproof building capable of containing the Engine, with its drawings and workshops necessary for its completion.\textsuperscript{163}"

**Entry into Politics**

Although Babbage was encountering difficulties in the construction of the Difference Engine, he still continued to pursue other outside interests. He now became actively engaged in politics.

\textsuperscript{160} Loc. cit.

\textsuperscript{161} Babbage, Henry P. \textit{op. cit.}, p. 124.

\textsuperscript{162} Babbage, C. \textit{Passages, op. cit.}, p. 80.

\textsuperscript{163} Babbage, C. \textit{Passages, op. cit.}, p. 81.

In 1829, a vacancy had occurred in the representation of the University of Cambridge at Parliament and William Cavendish, a recent honor graduate and member of the famous Cavendish family, was one of the candidates nominated to fill the vacancy. Babbage was selected as campaign chairman for William Cavendish and actively participated in securing his election.

Political opinions were becoming a strongly controversial subject in England at that time, and there were frequent elections. After the successful election of William Cavendish, Babbage served as campaign chairman on three other occasions before the end of 1832. These activities of Babbage undoubtedly gained him enemies, as well as friends, for the conservative element at Cambridge was undoubtedly offended by this new Lucasian Professor backing reform candidates.

The cause of the Difference Engine certainly was not helped when Babbage actively, but unsuccessfully, backed the opponent of

166 Babbage, C. Passages, op. cit., p. 260.
168 The Times. London: No. 15,011, Friday, November 16, 1832, p. 3.
Mr. Goulburn, for Mr. Goulburn later was to be Chancellor of the Exchequer from whom Babbage was to seek funds for the Difference Engine.

Writings of 1829

While carrying out work on the Difference Engine and engaging in politics, Babbage was not ignoring his writings. In 1829, he produced the following: "Account of the Great Congress of Philosophers at Berlin on the 18th September 1828,"170 "Proportion of Birth of the Two Sexes Amongst Legitimate and Illegitimate Children,"171 "Note on the Description of Mammalia,"172 and the important "Introductory View of the Principles of Manufactures."173

Berlin Congress

The paper on the Berlin Congress was for the purpose of calling


the attention of British scientists to the important advantages which might arise from an annual meeting of "cultivators of the natural sciences." This paper helped lead to the formation of the British Association for the Advancement of Science in 1831.

Proportion of Births

The paper entitled "A Letter to the Right Hon. T. P. Courtenay on the proportionate number of Births of the two Sexes under different circumstances," was a result of Babbage's interest in life assurance societies and the statistics he had collected on births, deaths, marriage, and age of parents at birth of children. (The last breakdown may have been added for those interested in studying theories of population, for Malthus was a friend of Babbage).

Babbage said the paper was published to encourage others "to promote inquiry and elicit additional information." He did not make a complete analysis of the statistics collected but noted that in births "the excess of males above females is less amongst...


175 A. M. C. op. cit., p. 306.


177 Babbage, C. Passages, op. cit., p. 433.

legitimate children." He sought an answer to this but correctly concluded that there was insufficient information and encouraged others to "add their knowledge by the publication of similar enumerations."  

Description of Mammalia

This article by Babbage proposed that those interested in quickly describing strange mammalia should carry previously prepared sheets of 48 brief questions, each question answerable by a number. The intention was that these answers would adequately describe new mammalia seen by persons traveling in foreign lands.  

The article is of interest to this study because the idea is quite similar to one later proposed by Babbage for use in observing factories.

Introductory View of the Principles of Manufactures

This 8k-page essay entitled, "Introductory View of the Principles of Manufactures," was the most important contribution Babbage made.

179 Ibid., p. 90.
180 Ibid., p. 91.

Charles Darwin was among those who attempted to explain these statistics published by Babbage. Ref. Darwin, Charles The Descent of Man, and Selection in Relation to Sex. New York: D. Appleton and Co., 1890, p. 244.

182 Babbage, C. Economy of Machinery and Manufactures, op. cit., Chapter XII.
made in 1829. It formed the Introduction to the machinery volume, volume VIII, of the new *Encyclopædia Metropolitana*, and later became the core of Babbage's important book, *On the Economy of Machinery and Manufactures*.

It is of interest to this study to note that the subject of this introductory essay was different from articles Babbage had previously written. Babbage's articles on the application of machinery to the calculation of mathematical tables were the closest he had previously come to writing on manufacturing.

Babbage undoubtedly knew a great deal about machinery and manufacturing, but how did he happen to write this introductory essay which later was expanded into the book, *On the Economy of Machinery and Manufactures*?

Some factors which may have contributed to the writing of this introductory essay are as follows. Babbage had invented tools and machinery for the construction of the Difference Engine. He had visited many factories and studied their operations. He had been

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Note: The above copy was used for reference because of its availability. This volume, however, was originally published in 1829.

184 Babbage, C. *Economy*, op. cit.

185 The Times. London: No. 15,011, Friday, November 16, 1832, p. 3.

See "Tools" Chapter IV.

associating with some of the leading machinists of the time. At least two of Babbage's close associates and teachers in science, Dr. Wollaston and Sir William Herschel, had been expert machinists and students of manufacturing.

Further factors which may have influenced Babbage's writing of this introductory essay were his and his scientific friends' previous articles in the Encyclopedia Metropolitana. Also Dr. Olinthus G. Gregory may have been a big factor, for he and Babbage had been acquainted since the days they were both charter members of the Astronomical Society and Dr. Gregory was advisor to the Encyclopedia Metropolitana. One further factor which certainly influenced the writing of Babbage's introductory essay was the general plan of the Encyclopedia Metropolitana for this was conducive to using such introductory essays.
The above are some of the factors which may have been contributory to Babbage's writing of the "Introductory View of the Principles of Manufactures." The contents of this essay contained some of Babbage's important industrial management concepts, but they are so closely related to those of his book, *On the Economy of Machinery and Manufactures*, that they are discussed together in Chapters V and VI of this dissertation.

**Year 1830**

The year 1830 found Charles Babbage still active in many things, even though he was having difficulties with the financing of the Difference Engine. For some unknown reason, he had taken time to determine the frequency of appearances of the various letters in different languages. His findings were published in the *Correspondence Mathématique et Physique*. This year Babbage also became very vociferous in his attack on the Royal Society of London and published the book, *Reflections on the Decline of Science in England, and of Some of its Causes*.

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Decline of Science

As early as 1827 Babbage had been a member of a Royal Society committee which made recommendations intended to return the Royal Society to a more truly scientific body. These recommendations were blocked, however, by the non-scientific members of the Royal Society Council.

Babbage and others continued to protest against the party in control of the Royal Society and their "system of management." In spite of these protests the non-scientific members, in 1830, were able to maintain their control by electing the Duke of Sussex as President by a slim margin of votes over John Herschel, the candidate of the scientific interests.

The "canvassing had been carried on by both parties with the rancour that was then usual in a political contest" and this defeat of the scientific interests stimulated Babbage to make his views public by publishing, Reflections on the Decline of Science in England, and on Some of its Causes. He hoped the book would "ultimately do some service to science," and, although he knew

196 Lyons, op. cit., p. 245.
197 Loc. cit.
198 Ibid., p. 44.
199 Lyons, op. cit., p. 250.
200 Babbage, C. Decline of Science, op. cit., p. 5.
it would make enemies, he hoped what he had written would "not give just reason for the permanence of such feelings." The book did do service to science by helping return the Royal Society to more scientific endeavors, but it was so personal in places that it made many enemies for Babbage.

Two topics discussed in this book are of interest to this study. First, in discussing the reciprocal influence of science and education, Babbage criticized the educational system of England as concentrating too much on the "classical and mathematical pursuits." He recognized that educational progress had been made

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201 Loc. cit.

202 Lyons, op. cit., Chapter VII.


Sheepshanks, op. cit., pp. 40 ff.

Others, such as John Herschel, had more quietly been advocating the improvement of English science. Ref. Decline of Science, op. cit., Preface.


Babbage's Decline of Science was answered by the pamphlet "On the Alleged Decline of Science in England" by A Foreigner (Professor Gerard Moll), London: T. & T. Boosey, 1831.

203 Babbage, C. Decline of Science, op. cit., Chapter I.

204 Ibid., p. 3.
during the past fifteen years but felt that the students should study more of the following groups of subjects: modern history, law of England, and civil law; political economy and applications of science to arts and manufactures; chemistry, minerology, and geology; zoology and botany. This underlined portion (not underlined in the original) is of interest for it is the topic Babbage covered in his book, *On the Economy of Machinery and Manufactures* and the topic on which he proposed to lecture at Cambridge.

The second topic of interest in the Decline of Science was Babbage's discussion of "The Art of Observing." This is set forth in Chapter VII.

**Babbage and South vs. Sheepshanks and Airy**

Babbage and James South, a well known British astronomer, had been friends at least from the time they were both charter members of the Astronomical Society. Both were closely associated as leaders in the reform movement to improve British science. In 1829, South was elected President of the Astronomical Society and

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206 See this Chapter, "Appointment as Lucasian Professor."


209 Lyons, *op. cit.*, Chapter VII.
Rev. Richard Sheepshanks, a wealthy scientist, was elected Secretary. The bad feelings which apparently had previously existed between South and Sheepshanks now broke into the open and continued in a very bitter running feud for years. Babbage sometimes took the side of South, as he did over a dispute about a Royal Charter and in a famous court trial over a scientific instrument built for South. Sheepshanks was often supported by George Airy, a promising young scientist and professor at Oxford but one who apparently was not always too careful with the truth.

Through the years, as a result of these feuds, South lost the friendship of many of his scientific friends and Babbage met severe criticism and loss of prestige.

Optimum Color of Paper and Ink

Babbage's single publication for the year 1831 was, Specimen of Logarithmic Tables, printed with different coloured inks and on variously-coloured papers. Only one copy of this twenty-one volume work was printed, for it was done as an experiment to ascertain

211 Lee, op. cit., LIII, p. 9; LIII, p. 273
212 Babbage, C. Exposition of 1851, op. cit., Chapter XII.
Macfarlane, op. cit., pp. 110 ff.
213 Loc. cit.
"the tints of paper and colours of inks least fatiguing to the eye." One hundred and fifty-one variously coloured papers were chosen to be printed with tables of logarithms in over ten colors of ink.215

Babbage desired to know the best combination of colors to use so that the tables from the Difference Engine would be most usable.216 He was a great believer in tabulating data, and many of his endeavors were aimed at making tables more accurate and more readable.

British Association for the Advancement of Science

Babbage's "outspoken attack on the management of the Royal Society...contributed materially to the origin of" the British Association for the Advancement of Science, in 1831.217 This association helped further the development of British science through a better exchange of information between the various branches of science. As trustee of the British Association, from 1832 to 1838, Babbage strongly encouraged additions to the association which would

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217 A. M. C. op. cit., p. 306.
provide for a closer alliance between science and the commercial and manufacturing interests; but he failed to achieve his full objective. In 1833 Babbage was successful in establishing the Statistical Section as a recognized part of the British Association.

Constants of Nature and Art

Early in 1832 Babbage wrote a public letter to David Brewster, "On the Advantages of a Collection of Numbers, to be Entitled the Constants of Nature and Art." In this letter he proposed that it "would be of the greatest advantage to all classes of the scientific world" if the various united academies would collect and publish "all those facts which can be expressed by numbers." He indicated the need for data about subjects such as the following: astronomy, atomic weights, chemical compositions, metals, mammalia, vegetables, geography, velocities, population, buildings, weights and measures, dates, etc.

218 Loc. cit.


220 Ibid., p. 334.
221 Loc. cit.
222 Ibid., pp. 334-339.
Babbage realized the magnitude of making this collection of all the constants of nature and art and suggested a plan whereby three of the academies of Europe should alternate in collecting this data from existing sources and keep it up to date. He concluded his letter as follows:

I am confident that many a weary hour, now wasted in the search for existing knowledge, will be devoted to the creating of new, and that it will thus call into action a permanent cause of advancement towards truth, continually leading to the more accurate determination of established facts, and to the discovery and measurement of new ones.

Among the constants Babbage desired collected were those on "Power of Man and Animals." He suggested the following:

A man labouring ten hours per day will saw ( ) square feet of deal--ditto ( ) elm--ditto ( ) oak, &C.--ditto Portland stone--ditto Purbeck--Days labour in mowing, ploughing--& c. &c. every kind of labour--Raising water one foot high--horse do.--ox or cow do.--camel.

On the Economy of Machinery and Manufactures

Babbage published the first edition of his monumental book, On the Economy of Machinery and Manufactures, June 8, 1832. It met with immediate success for "In two months from the publication of the first edition of this volume, three thousand copies were in the hands of the public." By November 22, 1832, Babbage had

223 Ibid., p. 340.
224 Ibid., p. 336.
226 Ibid., p. vi.
revised the first edition and sent the second edition to press.\textsuperscript{227} The third edition followed quickly and was issued February 11, 1833.\textsuperscript{228} There was also a fourth edition and reprints, American editions and reprints, German, French, Italian, and Spanish translations.\textsuperscript{229} The total sales of the book are not known, but the four English editions alone sold about 10,000 copies.\textsuperscript{230} (Years later Babbage mentioned making some changes in the contents of On the Economy of Machinery and Manufactures in preparation for a new Italian Translation, but there is no evidence to indicate that this was ever published.)\textsuperscript{231}

This book made important contributions to the historical development of industrial management concepts. They are too lengthy to discuss here and are discussed in Chapters IX and X. The contents of this book are presented in Chapters V and VI.

Purpose of the Economy of Machinery and Manufactures

Babbage stated the purpose of the Economy of Machinery and Manufactures to be as follows:

\begin{itemize}
\item \textsuperscript{227} Ibid., p. ix.
\item \textsuperscript{228} Ibid., p. xii.
\item \textsuperscript{229} Babbage, C. \textit{Passages}, op. cit., p. 495.
\item A. M. C. \textit{op. cit.}, p. 304.
\item \textsuperscript{231} Babbage, C. \textit{Passages}, op. cit., p. 440.
\end{itemize}
I have not attempted to offer a complete enumeration of all the mechanical principles which regulate the application of machinery to arts and manufacturers, but I have endeavored to present to the reader those which struck me as the most important, either for understanding the actions of machines, or for enabling the memory to classify and arrange the facts connected with their employment. Still less have I attempted to examine all the difficult questions of political economy which are intimately connected with such inquiries....

It has been my endeavor, as much as possible, to avoid all technical terms, and to describe in concise language the arts I have had occasion to discuss. In touching on the more abstract principles of political economy, after shortly stating the reasons on which they are founded, I have endeavored to support them by facts and antidotes; so that whilst young persons might be amused and instructed by the illustrations, those of more advanced judgment may find subject for meditation in the general conclusions to which they point....

The difficulty of understanding the process of manufacturers has unfortunately been greatly overrated. To examine them with the eye of manufacturer, so as to be able to direct others to repeat them, does undoubtedly require much skill and previous acquaintance with the subject; but merely to apprehend their general principles and mutual relations is within the power of almost every person possessing a tolerable education.

Reasons for Writing the Economy of Machinery and Manufactures

One question of interest to the student of management history is, why did Charles Babbage write the book, *On the Economy of Machinery and Manufactures*?

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232 Babbage, C. *Economy*, op. cit., p. iii.

233 Ibid., p. v.

234 Ibid., p. iv.
As noted previously, in the Preface to this book Babbage wrote, "it was my intention to have delivered the present work in the form of a course of lectures at Cambridge; an intention which I was subsequently induced to alter." This may be part of the answer, for in the Decline of Science, of 1830, one of the courses which Babbage proposed for college students covered political economy and the applications of science to arts and manufactures. Also the previously noted reference of Richard Sheepshanks indicated that possibly Babbage prepared the material for such a course but did not lecture "from the difficulty in never getting a class."

To lecture at Cambridge at this time "there were difficulties to surmount; no allotted term for the lectures, no allocated hour of the day, scarce any available lecture-room." Possibly with the limited facilities Babbage lost out to George Airy, who continued to lecture after giving up the Lucasian Professorship. This

235 Ibid., p. iii.

See this Chapter, "Appointment as Lucasian Professor."

236 Babbage, C. Decline of Science, op. cit., p. 6.

237 Sheepshanks, op. cit., p. 78.


may have been the beginning of the long running conflict between Babbage and Airy. 2h0

Another fact, however, which appears to be important to the publishing of On the Economy of Machinery and Manufactures is the success of John Herschel's book, A Preliminary Discourse on the Study of Natural Philosophy. 2h1 This book of Herschel's was published in 1830 as part of the Lardner's Cabinet Cyclopaedia and quickly received wide recognition and praise. It was known "for power and elegance of language, for clearness of illustration, for sound and far-sighted judgment." 2h2 It treated the methods of scientific research since the time of Francis Bacon and "formed a guide and inspiration...to all the British scientists of the nineteenth century." 2h3

Babbage, after seeing the success of Herschel's book, apparently decided to expand his essay, "Introductory View of the Principles of Manufactures," 2h4 into a similar book on machinery and manufacturing. This supposition is substantiated by the following excerpt from a

2h0 Loc. cit.


2h3 Macfarlane, op. cit., p. 136.

2h4 Babbage, C. "Introductory View of the Principles of Manufactures." Encyclopaedia Metropolitana, op. cit.
letter from Whewell to Jones, February 19, 1832.

I think exactly as you do about Babbage's book. He told me also about his project of publishing a book 'like Herschel's' at which I could not quite suppress an internal smile. But still there is a great deal of ingenuity in his speculations, and the one you mention about skilled labour is, I think, the brightest of them. Moreover, the book is of a kind which will receive its full measure of praise in these days.245

An analysis of the contents and date of the above letter, plus the pattern of Babbage's previous writings, leads one to conclude that the success of John Herschel's Discourse on Natural Philosophy played a great part in inducing Babbage to write his book, On the Economy of Machinery and Manufactures. Babbage's lack of publications during 1831 was probably due to his spending this time visiting manufactories246 and reading House of Commons and other reports247 for material to expand the essay, "Introductory View of the Principles of Manufactures," into the book, On the Economy of Machinery and Manufactures. Other factors influencing this book are indicated in Chapter VIII.

Candidate for Parliament from Finsbury

At this time in England there had been growing agitation for Parliamentary reform. This reform was finally accomplished by the passing of the Reform Bill of 1832, which expanded the electorate

\[245\] Todhunter, op. cit., pp. 141-142.

\[246\] Babbage, C. Passages, op. cit., pp. 384-386.

\[247\] Babbage, C. Economy, op. cit., p. v.
and redistricted the Parliamentary seats. One of the new London
districts created was the Borough of Finsbury. This was primarily
a manufacturing part of the city, with 10,537 persons entitled to
vote under the new 10 pound household suffrage provision. In the
first election of the Borough of Finsbury, Babbage put himself for­
ward as a candidate for one of the two newly created Parliamentary
seats.

Late in August, 1832, the campaign in Finsbury began to get
underway with four candidates announcing themselves, but Babbage had
not yet publicly announced his candidacy. Finally on November
16, Babbage's committee, after some difficulty in being formed, was
announced as being active. The cause of the difficulty in getting
Babbage's committee formed is not known, but it may have been due
to his completing the second edition of On the Economy of Machinery
and Manufactures, for it went to press one week after he began his
campaign.

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248 McCarthy, Justin The Epoch of Reform, 1830-1850. New York:
Charles Scribner and Sons, n. d.

Trevelyan, George Macaulay Lord Grey of the Reform Bill.

249 The Times. London: No. 15,010, November 15, 1832, p. 3.
250 The Times. London: No. 15,011, November 16, 1832, p. 3.
251 The Times. London: No. 14,937, Wednesday, August 22,
1832, p. 3.
252 The Times. London: No. 15,011, Friday, November 16,
1832, p. 3.
253 Babbage, C. Economy, op. cit., p. ix.
Babbage was strongly backed by the London Times which wrote,

[Babbage] has, we understand, the best chances of success. Besides his sound political views he is, perhaps, the most eminent of living men of science, abounding as the present age does in learned professors. Mr. Babbage has taught philosophy to go hand with utility and has shown that the profoundest acquaintance with the abstrusest parts of abstract knowledge is compatible with, nay, is conducive to, the most practicable and beneficial results in almost every detail of mercantile, manufacturing, and ordinary life. The choice of such a man will do honor to the new Borough of Finsbury, and will be an appropriate reward for a life dedicated...to the benefit of his fellow citizens.254

The New Monthly Magazine also backed Babbage as follows, "It would give us, indeed, peculiar pleasure to see men like...Mr. Babbage--whose science is a part of a large mind, and not an excuse for a small one--returned to a Reformed Parliament...."255

On November 22 Babbage opened his speaking campaign. He was introduced as "a man so practically acquainted with the manufacturing interest of this country, particularly in its machinery department...."256 He was not an able political speaker and was sharply criticized for some of his views and for receiving 12,000 pounds from the government for a calculating machine which was reported to be imperfect. To this last charge Babbage replied, "he had never

254 The Times. London: No. 15,011, Friday, November 16, 1832, p. 3.


256 "Finsbury Election--Mr. Babbage." The Times, London: No. 15,017, Friday, November 23, 1832, p. 1.
received a single farthing of the public money for his invention" and was only responsible "to superintend its erection," 257

Babbage continued his speaking campaign in Finsbury. He was backed as a "thorough reformer" 258 and a "supporter of the mercantile and manufacturing interests." 259 He probably was not the best campaigner for one of his backers advertised that "his present honest diffidence will mature into decision, and that ere long we shall find him in practice what he now is in principle." 260

Babbage had started his campaign late and apparently was not an astute politician. 261 This probably influenced the outcome of the election. When the second and final day of polling was complete, the vote stood as follows: Grant, 4,293; Sparkle, 2,857; Babbage, 2,337; Wakely, 2,189; Temple, 789. 262 Since only the two highest were elected, Babbage lost by 520 votes.

257 Loc. cit.


259 The Times. London: No. 15,028, Thursday, December 6, 1832, p. 3.


261 The Times. London: as follows: No. 15,017, Friday, November 23, 1832, p. 1; No. 15,021, Wednesday, November 28, 1832, p. 3; No. 15,029, Friday, December 7, 1832, p. 2.

One wonders what might have happened if Babbage had started his campaign earlier, had been a better speaker, and had been clearer in his views. Regrettably by this defeat Babbage was not able to contribute to the Parliamentary solution of the growing manufacturing problems.

Although Babbage is said to have stood for election in Finsbury in 1834, this study found no evidence of the times to substantiate this. Following the defeat of 1832 Babbage was not active in politics again.

The year 1832 probably marks the pinnacle of Babbage's life. In the succeeding years he was to achieve further success, but at a decreasing rate. Also, more disappointments and disillusionments were to mar his career.

Chapter Summary

In 1823 Charles Babbage was thirty years of age, well educated, skilled in mathematics, and acquainted with many of the most eminent scientists of England and France. With the assistance of friends he received financial support from the English government for the construction of his Difference Engine, the machine which was to automatically calculate and print mathematical tables.

263 A. M. C. op. cit., p. 304.

Between the ages of thirty and forty Babbage supervised the construction of the Difference Engine and displayed a wide variety of other interests and activities. The papers and articles he wrote during these years were on such subjects as the following: mechanical calculation, mathematics, barometric measurements, magnetism and electricity, diving bell, method of expression by signs the action of machinery, scientific congress at Berlin, statistics of birth and deaths, description of mammalia, frequency of use of letters in different languages, constants of nature and art, and an introductory essay to volume III of the *Encyclopedia Metropolitana* entitled, "Introductory View of the Principles of Manufactures."

This last article, written in 1829, discussed the principles of manufacturing which was a different subject matter than any of Babbage's previous articles. Its contents are presented in Chapters V and VI of this dissertation for they form the core of Babbage's book, *On the Economy of Machinery and Manufactures*. Some of the factors which may have contributed to Babbage's writing of this introductory essay are as follows: Babbage had invented tools and machines to produce parts for the Difference Engine; to learn better ways to produce things he had visited and studied many British and foreign workshops; he had been associated with many leading machinists and students of manufacturing; many of his friends were contributors to the *Encyclopedia Metropolitana*; the advisor to the publisher was a friend of Babbage; and the general plan of this encyclopedia was conducive to the use of introductory essays.
(See Chapter VIII for further discussion of people and circumstances which influenced Babbage.)

Besides the above activities Babbage edited *Scriptores Optici* in 1823—a collection of papers on optics; wrote *A Comparative View of the Various Institutions for the Assurance of Lives* in 1826—an excellent and classic book; published *The Table of Logarithms of the Natural Numbers*, from 1 to 108,000 in 1826—very accurate and printed only after careful study of best principles for presenting tabulated data; published *Reflections on the Decline of Science in England, and Some of its Causes* in 1830—an attack on English science, especially the Royal Society of London and its methods of operation; and in 1832 produced his memorable and important *On the Economy of Machinery and Manufactures*. Meanwhile, in 1828, through the efforts of John Herschel and other friends, Babbage was appointed Lucasian Professor of Mathematics at Cambridge University. Although Babbage performed very few duties in this position it did influence his activities, as indicated below.

The book *On the Economy of Machinery and Manufactures* contained the majority of Babbage's industrial management concepts; met with immediate success; and went through two editions in 1832, one in 1833, and one in 1834. There were also reprints; American editions; German, French, Italian, and Spanish translations.

The book, *On the Economy of Machinery and Manufactures*, has been recognized as one of the best early books containing industrial management concepts. At least two factors might have caused Babbage
to publish this book built around the earlier introductory essay to
the *Encyclopedia Metropolitana*. First, he had intended to cover
much of the contents in a series of lectures at Cambridge University
but, being unable to do this, published the book. Secondly,
Babbage's good friend John Herschel had just published a very success­
ful book on Natural Philosophy and Babbage decided to produce one on
manufacturing 'like Herschel's'. (The contents of this book are
presented in Chapters V and VI, and its contributions to the histori­
cal development of industrial management concepts discussed in
Chapters IX and X.)

Other activities of Babbage during these ten years included at
least three trips abroad (1824, 1826, and 1827), the last being to
improve his health after the death of his second son and wife.
Babbage also spent much time trying to return the Royal Society of
London to more scientific endeavors but was not immediately success­
ful and some of his attacks made bitter enemies. In 1829 Babbage
actively entered politics and in 1832 became a reform candidate for
Parliament from the Borough of Finsbury. The popularity of his
recent book on manufacturing helped him be identified with the manu­
facturing interests but, due to his late campaign start and his
ineptness as a politician, he lost the election to other reform
candidates.

While Babbage was thus active in many things the construction
of the Difference Engine began to run into financial difficulties
in the late 1820's. Finally after delays, disputes, discussions,
the support of Babbage's friends and the Royal Society, and much optimism from Babbage on the imminent success of the project, the Government gave much more financial assistance. Construction was resumed in 1830 and as late as 1832 the work seemed to be progressing satisfactorily.

The years from 1823 through 1832 were very productive ones for Babbage. The Difference Engine had become the center of his attention and many people expected great things from it. However, Babbage's interests continued to cover a great many other areas, only one of which was the study of manufacturing. Babbage first published his ideas on manufacturing in the *Encyclopedia Metropolitana* in 1829. He later expanded these into his 1832 book, *On the Economy of Machinery and Manufactures*. The wide and immediate success of this book probably marked the height of Babbage's career.
CHAPTER IV

DECLINE AND DISILLUSIONMENT

Introduction

In the first forty years of his life (1792-1832), Charles Babbage had become internationally famous through his writings, his scientific activities, and the Difference Engine. By the end of 1832 his book, *On the Economy of Machinery and Manufactures*, had made him one of the most popular authors of the day; and, although he had been unsuccessful in gaining a seat in Parliament, this year marked the height of his career. The last forty years of his life (1833-1871) continued to contain personal achievements; but Babbage gradually declined from the heights to which he had climbed until, at the age of almost 80, he died a disappointed and disillusioned man. These last forty years are covered in this chapter.

Third and Fourth Editions of *On the Economy of Machinery and Manufactures*

Babbage's latest book, *On the Economy of Machinery and Manufactures* met with popular success and, only eight months after the issuance of the first edition, the third edition went to press.


The following told by Harriet Martineau indicates somewhat the popularity of this book. "Mr. Babbage, calling on me one day, when he was in high spirits about the popularity of his own work, 'Machinery and Manufactures' said, Now there is nobody here to call us
February, 1833. It contained practically no changes from the second edition but in its Preface Babbage continued to feud with the book sellers. This feud started when Babbage, in the first edition, illustrated the chapter, "On Combinations Among Masters Against the Public," by using the policies of the book sellers as an example of combination against the public. 2 When some of the book sellers objected to Babbage's illustration he expanded his arguments in the preface and text of the second edition. To this some book seller printed a "Reply to Mr. Babbage," and Babbage in turn retorted in the preface to the third edition. 3 This feud accomplished little for either Babbage or the book sellers but it did detract from the merits of On the Economy of Machinery and Manufactures. 4

Fortunately, in the fourth edition of this book, issued January, 1835, Babbage made no further attacks on the book sellers. 5

1 Cont.

vain, we may tell each other that you and I are the only people in the market. I find no books are selling but yours and mine," Ref. Chapman, Maria Weston, editor, Harriet Martineau's Autobiography. Boston: Houghton, Mifflin and Co., 1877, p. 201.

2 Ibid., Chapter XXXI.

3 Ibid., p. vi-xii.

4 A letter from Charles Dickens to Babbage, April, 1843, indicates that Babbage continued some activity on behalf of authors. Dickens thought Babbage's ideas were good in theory but unworkable in practice. Ref. Hutton, Lawrence, editor, The Letters of Charles Dickens, p. 106; The Works of Charles Dickens, XIX, New York: Bigelow, Brown & Co., n. d.

5 Babbage, C. Economy, op. cit., p. xlii.
last edition contained no changes except for the inclusion of a few illustrations, which had appeared in the 1833 German translation, and an index. One of the added illustrations was on the topic of "Employment of materials of little value." It indicated how the slaughter houses near Paris used all by-products from the slaughtering of horses; making use of such things as hair, skin, blood, shoes, hoofs, fat, bones, intestines, etc. The last two paragraphs of this illustration are quoted below to indicate the extent to which they carried this.

Even the maggots which are produced in great numbers in the refuse, are not lost. Small pieces of the horse flesh are piled up, about a half a foot high; and being covered slightly with straw to protect them from the sun, soon allure the flies, which deposit their eggs in them. In a few days the putrid flesh is converted into a living mess of maggots. These are sold by measure; some are used for bait in fishing, but the greater part as food for fowls, and especially for pheasants. One horse yields maggots which sell for about 1s., 5 d.

The rats which frequent these establishments are innumerable, and they have been turned to profit by the proprietors. The fresh carcass of a horse is placed at night in a room, which has a number of openings near the floor. The rats are attracted into it, and the openings then closed. 16,000 rats were killed in one room in four weeks, without any perceptible diminution of their number. The furriers purchase the rat skins at about 3s. the hundred.

6 Ibid., pp. 393-408.
7 Ibid., pp. 11-12.
8 Ibid., p. 395.
Statistical Societies

As noted in Chapter III, Babbage had been instrumental in establishing the British Association for the Advancement of Science in 1831. In 1832 he took an active part in their proceedings at Cambridge; and, in 1833, at a meeting attended by Richard Jones, Malthus, M. Quetelet, and a few others, Babbage instigated the establishment of the Statistical Section of the British Association. The first official meeting of this section was held in 1834, and in 1835 Babbage was elected President of this section and chairmaned its meetings at Dublin. At the latter meetings Mr. Babbage showed, by several curves, the progress and consequence of cooperative shops amongst workmen. He said, "they always failed; partly from the ignorance of the committee of purchases in the skill necessary to enable them to lay in their stores on as good terms as the regular traders, and partly from the demoralizing effect on the members of the committee from being bribed by the wholesale dealer.

At these Dublin meetings Babbage also commented on his idea of using concentric rings of trees to provide data on weather conditions.


11 Loc. cit.

12 Proceedings of the Fifth Meeting of the British Association for the Advancement of Science, held in Dublin 1835. Dublin: Hardy, 1835, p. 10.

13 Ibid., p. 67.
for previous years. He felt this data could be assembled for many past years, by collecting the information from living trees, as well as the dead ones preserved in the English peat bogs.¹⁴

A direct outgrowth of the Statistical Section was the formation of the Statistical Society of London in 1834, with Babbage again "the original proposer and founder."¹⁵ This Society met with immediate success and was soon publishing its own Journals and collecting statistics on such subjects as "Statistics of Production," including manufacturing and commercial statistics.¹⁶

**Babbage's Social Life**

Judging from Babbage's activities, one might guess that he was all work and no play. This, however, was far from true, for Babbage was very much in the center of London's social activities. He not only dined out with everybody of note to be found in London,¹⁷ but "he was accustomed to invite scientific men, who happened to be in London, to breakfast with him, and then, putting the engine to work

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¹⁴ Ibid., pp. 116-117.


[model of the Difference Engine], explain its mechanism and exhibit its calculations.\textsuperscript{18}

For years Babbage's "Saturday evening receptions were very fashionable, and invitations for them were eagerly sought after."\textsuperscript{19} It was said, "one of three qualifications, however—intellect, beauty, or rank—was absolutely indispensable, and without one of these credentials no entrance was obtainable."\textsuperscript{20} These delightful entertainments "made Mr. Babbage's house almost as famous for the flavor of its society as Charles Lamb's was at an earlier day."\textsuperscript{21} Many writers made reference to these famous Saturday evening soirees\textsuperscript{22} and Babbage, himself, wrote of various incidents which occurred at them.\textsuperscript{23}

\begin{itemize}
  \item \textsuperscript{18} Dodge, W. S. "A Philosopher and His Friends." Lakeside Monthly, Chicago, IX, p. 243.
  \item \textsuperscript{19} Fyvie, \textit{op. cit.}, p. 193.
  \item \textsuperscript{20} \textit{Loc. cit.}
  \item \textsuperscript{21} Dodge, \textit{op. cit.}, p. 241.
  \item \textsuperscript{23} Babbage, C. \textit{Passages}, \textit{op. cit.}
\end{itemize}
One writer mentioned that at Babbage's parties she often met such guests as the following: Lady Lovelace (formerly Ada Byron), Livingstone, Lanseer, Charles Dickens, Archbishop Whately, Sir Charles Eastlake, Turner, M. Van de Weyer, Rogers, Hallman, Sir Charles and Lady Lyell, the Horner Family, the Carrick Moore Family, Barry Cornwall and Mrs. and Miss Procter, Lady Bell, Lady Beecher, the Pollock Family, the Kemble Family, Lady Davy, Mrs. Leychester Stanhope, Lady Chantrey, Mrs. Norton and many others well known to London Society. 24

Many other notables are known to have attended these glorious soirées but little would be accomplished by listing their names here, for it is quite evident that Babbage's house was one of the centers of fashionable London society for many years. 25

Babbage was also a frequent visitor at many of his friends' homes. One writer said that it was "Babbage who I met more frequently than any other Philosopher not only at Mr. Senior's but at Mr. and Miss Rogers, at Baroness Burdette Coutts, Sir Charles Eastlake's, at Mr. Carrick Moore's, at Lady Chantrey's, Lady Bell's, Mr. Bates and many other houses. I also met him staying at country houses... Mr. Babbage had not a large correspondence for the fact that he lived so much with his friends, that he had little occasion to write more than answers to invitations, etc. If this had not been the case, his collection of autographs would have been most interesting, from the large number of remarkable men and women with whom he lived on terms of intimacy. 26 It was said, "Mr. Babbage...would not willingly

25 See Introductory chapter for list of some of the people Babbage knew.
26 M. L. op. cit., p. 47.
exclude himself from a house where he might not unfrequently meet with people of rank."  

Babbage was closely associated with most of the writers and artists of London for, in the early 1830's, he had become a close friend of Samuel Rogers, the famous poet, whose house and breakfast parties were the center of literature and art in London. Until the poet's death in 1855 "few persons possessed more of Mr. Rogers regard than 'the Babbage' as he called him." "Nothing pleased Mr. Babbage more than to sit vis-a-vis at a table with the old poet, and with a bottle of port between them, to draw out from his memory anecdotes and descriptions of the men of by gone days."  

Babbage's Personality  

From Babbage's various activities and attitudes one can conclude that he was an unusual person. Several writers, however, give us some details as to how he was regarded by his contemporaries.

27 Sheepshanks, Richard. A Letter to the Board of Visitors of the Greenwich Royal Observatory in Reply to the Calumnies of Mr. Babbage at their Meeting in June 1853, and in His Book Entitled The Exposition of 1851. London: G. Barclay, 1854, p. 50.  
29 Clayden, op. cit.  
M. L. op. cit., pp. 3 ff.  
30 M. L. op. cit., pp. 11-12.  
31 Dodge, op. cit., p. 241.
For example, William Whewell, in 1829, wrote the following, "Babbage has been here in the capacity of professor, and I have really enjoyed his society much, having seen him more closely than I had done before, but his anxiety about success and fame of his machine is quite devouring and unhappy." 32

Mr. James Forbes, on meeting Babbage in 1831, wrote, "Mr. Babbage asked me to go and dine with him. I had occasion to see a good deal of his character, which is very peculiar and particularly interesting to me...It was with the greatest difficulty that I escaped from him at two in the morning after a most delightful evening." 33

Harriet Martineau, writing around the year 1833, said,

as for Babbage, it seems to me that few men were more misunderstood. His sensitiveness about opinions perverting other people's impressions of him quite as much as his of them. For one instance: he was amused, as much as struck, by the very small reliance to be placed on opinion, public or private, for or against individuals: and he thought over some method of bringing his observation to a sort of demonstration. Thinking that he was likely to hear most of opinions about himself as a then popular author, he collected every thing he could gather in print about himself, and pasted the pieces into a large book, with the pros and cons in parallel columns, from which he obtained a sort of balance, besides some highly curious observations. Soon after he told me this, with fun and good humor, I was told repeatedly that he spent all his days in gloating and grumbling over what people said of him, having got it all down in a book, which he was perpetually poring over. People who so represented him had little idea what a domestic tenderness is in him, though his singular face seemed

32 Todhunter, op. cit., p. 97.

to show it, nor how much that was really interesting might be found in him by those who viewed him naturally and kindly.34

Mrs. M. Lloyd, in reminiscing about Babbage in 1880 said,

what struck me most in Mr. Babbage's character was his thoughtful kindness, his remarkable acuteness, and his almost painfully sensitive feelings...Mr. Babbage was tender in his friendship and bitter in his hatred...

* * *

...Though Mr. Babbage was ready to talk on any subject (but Music and Poetry) he never missed an opportunity of talking about his wonderful machine 'the difference engine' or the 'Leviathan' as he called it. He assured me that when it was finished it would 'analyze everything, and reduce everything to its first principles and so include further inventions, and in short almost supersede the human mind.'35

The expression of Mr. Babbage's face was very sad, but it quickly disappeared in conversation, though it returned to his face in repose. He indulged in the kind of mental anatomy with himself and others, which was very amusing, and most original. There was a look of overwork and mental strain in his countenance which made me right glad when we could persuade him to forget all his worries about his machines and latterly the organs, to spend a quiet day in the country...36

Thomas Carlyle in 1840, after an evening with Rogers, Milman, Babbage, Pickwick, Lyell, and a few others, in his sarcastic fashion wrote, "Babbage continues eminently unpleasant to me, with his frog mouth and viper eyes, with his hide-bound, wooden irony and the

34 Chapman, op. cit., p. 267.
35 M. L. op. cit., pp. 52-53.
36 Ibid., p. 56. The "organs" refer to the organ grinders which bothered Babbage so much in the latter part of his life. See "Street Nuisances" Chapter IV.
112

acridest egotism looking through it."37 Charles Darwin, in his Autobiography, recorded the following encounter between Carlyle and Babbage,

His [Carlyle's] talk was very racey and interesting, just like his writings, but he sometimes went too long on the same subject. I remember a funny dinner at my brother's, where, amongst a few others, were Babbage, and Lyell, both of whom liked to talk. Carlyle, silenced everyone by haranguing during the whole dinner on the advantages of silence. After dinner, Babbage, in his grimmest manner, thanked Carlyle for his very interesting lecture on silence. 38

Babbage's arch-enemy, Richard Sheepshanks, in 1854, spoke of him as follows,

I have always expressed my dislike for Mr. Babbage's quarrelsome and spiteful temper, his readiness to take offense, his implacable hatred, and his inordinate vanity which completely blinds him as to the consequences of his own conduct...He assumes, indeed, that he is more wise, more steadfast, more deep-sighted, and more honest than the rest of mankind.39

Some of Babbage's limitations may have been aggravated by a speech impediment for the same Richard Sheepshanks spoke of "Mr. Babbage's stammering answer" and of lectures "perhaps badly read" by Babbage.40 The following also indicates a possible speech defect for Babbage.


39 Sheepshanks, op. cit., p. 79.

40 Ibid., p. 37, p. 78.
I was setting in the row behind Babbage, about three above him, and had a complete view of his face when he rose to speak, and its contortions would have amused a phrenologist or physiognomist. He got on very well, i.e., with his usual hesitations, for a couple of minutes, whilst we were all attentioned to the oracle, when in a sudden he broke down; we encouraged him by clapping of hands for a minute or two, but all in vain, his wits went a-wool-gathering, and after diverse twist to his face to collect them, down he sat.

Charles Dickens on Babbage

Charles Dickens, like many English authors of his time, often based his characters on living persons. Thus it occurred that in his 1857 novel, Little Dorrit, Dickens based the character of Daniel Doyce on Charles Babbage. Although many of Dickens' characters were based on specific persons, his plots did not necessarily conform to true life. It is therefore difficult to always determine where the facts of Dickens end and the fiction begins; but the following seems to be Dickens' opinion of Charles Babbage in about 1855, as seen in the character of Daniel Doyce.

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1l DeMorgan, Mary A. Three Score Years and Ten. Reminiscences of the Late Sophia Elizabeth DeMorgan. London: Richard Bentley & Sons, 1895, p. 137.


Daniel Doyce's taking of a partner in the book does not mean that Babbage did; there is no known evidence of a similar true-life partnership.
He was not much to look at, either in point of size or in point of dress; being merely a short, square, practical looking man, whose hair had turned grey, and in whose face and forehead there were deep lines of cogitation, which looked as though they were carved in wood. He was dressed in decent black, a little rusty, and had the appearance of a sagacious master in some handcraft. He had a spectacle-case in his hand, which he turned over and over while he was thus in question, with a certain free use of the thumb that is never seen but in a hand accustomed to tools.

He spoke in that quiet deliberate manner, and in that undertone, which is often observable in mechanics who consider and adjust with great nicety. It belonged to him like his suppleness of thumb, or his peculiar way of tilting up his hat at the back every now and then, as if he were contemplating some half-finished work of his hand, and thinking about it.

It was evident that he had grown the older, the sterner, and the poorer, for his long endeavour.

...[he] had been much too accustomed to combine what was original and daring in conception with what was patient and minute in execution, to be any ordinary man.

Difference Engine Construction Stopped

Babbage's personality and life were influenced a great deal by his calculating machines, especially, in the latter half of his life. By early 1833 the construction of the Difference Engine had progressed sufficiently to enable a portion of its computational mechanism to be assembled. "The action of this portion completely

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45 Dickens, op. cit., I, pp. 125-126.
46 Ibid., p. 129.
47 Ibid., p. 131.
justified the expectations raised, and gave a most satisfactory assurance of its final success.\textsuperscript{49}

Since the beginning of the Difference Engine in 1823 the construction had been carried out in the workshop of Mr. Clement.\textsuperscript{50}

In recent years the Government had been paying Clement's bills for this work; after they were approved by Messrs. Darkin and Field, two leading engineers. Babbage, however, frequently advanced money to Clement due to the slowness of Government payments.\textsuperscript{51}

Clement was widely known for his excellent workmanship and for years many persons had sought his services. Clement's charges were so high, in fact, that more than one customer refused to pay without having the opinion of an arbitrator. On the Difference Engine work, however, Clement felt he did not make as much profit as on other work and therefore did not eagerly push it.\textsuperscript{52}

In early 1833 the Government completed the construction of new fireproof workshops for the Difference Engine near Babbage's home.\textsuperscript{53}

While arrangements were being made for the removal of the work to these new facilities Clement made a considerable increase in his charges for supervising it at a location away from his own

\textsuperscript{49} Babbage, C. \textit{Passages, op. cit.}, p. 82.
\textsuperscript{50} Ibid., p. 71.
\textsuperscript{51} Ibid., pp. 81-82.
\textsuperscript{53} Babbage, C. \textit{Passages, op. cit.}, p. 82.
establishment. Babbage believed the new rates were exorbitant and found it no longer convenient to advance Clement money. Furthermore, Babbage quarreled with Clement who "was not a good-tempered man, and...was in very bad health...This quarrel, however, was a most unlucky one for Mr. Babbage, not merely on account of the delay and loss thereby occasioned, but in depriving him of the person on whose mechanical skill and continuance he had hitherto depended."  

On April 10, 1833, Clement discontinued the construction of the Difference Engine and discharged the workmen employed on it. One of these was Joseph Whitworth, "who later amassed a fortune by utilizing as a mechanical engineer, the training which he had got from Babbage."  

It was said that when Clement withdrew from the work he "carried with him all the valuable tools that had been used in the work;  

55 Babbage, C. *Passages*, op. cit., p. 82.  
56 Sheepshanks, op. cit., p. 66.  
a proceeding the more unfortunate, as many of them had been invented expressly to meet the unusual forms and combinations arising out of the novel construction" 59 of the Difference Engine. In justice to Clement it should be said that an analysis of the known facts in this case does not indicate that he, "carried off" any tools, but probably merely kept them in his shop, which he had every legal right to do. 60 The Difference Engine was "carried off" from the tools. Clement did offer to sell the tools to Babbage, but Babbage declined the offer. 61

After much delay and discussion between Babbage, the Government, and Clement, the parts and drawings of the Difference Engine were finally moved to the new workshops in July, 1834. Authority was given to proceed with the construction, with the Treasury prepared, as soon as Clement's accounts were received, to "take into consideration what further proceedings may be requisite with a view to its completion." 62

Meanwhile, during this year of dispute, Babbage had been deprived of access to the drawings of the Difference Engine, and, "having naturally speculated on the general principles on which

59 Weld, op. cit., p. 383.
60 Ibid., p. 384.
61 Ibid., p. 383.
62 Babbage, C. Passages, op. cit., p. 83.
machinery for calculation might be constructed, a principle of entirely a new kind occurred to him, the power of which over the most complicated arithmetical operations seemed nearly unbounded.\(^\text{63}\) Upon re-examining the drawings of the Difference Engine, Babbage was sure he could either construct a much simpler Difference Engine or produce a new machine, the Analytical Engine, which would have a greater degree of usefulness and work more rapidly.\(^\text{64}\) Babbage by this time also wished to have some other agent besides Clement construct the machine.\(^\text{65}\)

While the above events were occurring, the Difference Engine was receiving more publicity. In June, 1834, Dr. Lardner lectured on it at the London Mechanics Institute \(^\text{66}\); and, in July, he reviewed it and its progress in the \textit{Edinburgh Review}.\(^\text{67}\) He stated that from 1829 "until the beginning of the year 1833, the progress of the work had been slow and interrupted. Meanwhile many unfounded rumors have obtained circulation as to the course adopted by the Government in this undertaking; and as to the position which Mr. Babbage stands with respect to it."\(^\text{68}\) The article ended by encouraging Babbage to

\(^{63}\) \textit{Loc. cit.}\n
\(^{64}\) \textit{Ibid.}, pp. 83-84.

\(^{65}\) \textit{Ibid.}, p. 85.

\(^{66}\) DeMorgan, \textit{op. cit.}, p. 203.

\(^{67}\) n. n. "Babbage's Calculating Engine." \textit{The Edinburgh Review}, LIX, No. 120, July, 1834, pp. 263-327.

\(^{68}\) \textit{Ibid.}, p. 325.
point out, "to the Government the course which they should adopt to remove the causes of delay," especially with "his present reputation and future fame depending in so great a degree upon the successful issue of this undertaking." 69

By September, 1834, Babbage was prepared to place his views before the Government, but due to delays and changes in Government, this did not occur. 70 Over the next few years there was much correspondence between Babbage and the Government, but with the confusion as to what were Babbage's intentions and with frequent changes in Government, no answer was received as to whether the Difference Engine or the Analytical Engine should be constructed. 71 If Babbage had been content to complete the Difference Engine before proposing so many possible changes, his life's dream might have been partially fulfilled. As it was, Babbage never did complete the construction of any calculating machine; but he never gave up hope. Through the following years Babbage devoted even more of his time and energies to this endeavor.

69 Ibid., p. 326.
70 Babbage, C. Passages, op. cit., pp. 85-86.
71 For more complete accounts of this see:
Babbage, C. Passages, op. cit., Chapter VI.
Weld, op. cit., Chapter XI.
Departure of Herschel

About this time another event occurred which may have had a considerable influence on Babbage's work and his life. Throughout the 1820's John Herschel, Babbage's close friend, had always been in the forefront in getting the Royal Society and others to support the Difference Engine. However, after the death of his mother in 1832, John Herschel prepared to leave England and carry out his long cherished project of taking astronomical observations of the southern heavens. In November, 1833, he and his family sailed for the Cape of Good Hope and were gone for four years before they made a triumphal return to England in 1838. Following this, Herschel spent a number of years concentrating on his astronomical reports.

If John Herschel had been available in England during the years following 1833, he might have again rallied the necessary support for Babbage's Difference Engine; and the course of events in the latter half of Babbage's life might have been changed. As it was, Babbage needed support and it was not forthcoming. In the preceding years Babbage had been critical of many others; now, when he needed their support, they were only critical of his actions in not completing the Difference Engine.

72 See Chapter III.


74 Lardner, op. cit., pp. 325 ff.
Analytical Engine

In September, 1834, Babbage began to supervise, in his own workshops, the design of his new calculating machine, the Analytical Engine. Much of the rest of his life and thousands of pounds from his fortune were spent on this project, which eventually filled hundreds of drawings and well over 6,000 pages of scribbling books.

Babbage seems to have leaned heavily on the advice of his mother who, at an elderly age told him, "My dear son, you have advanced far in accomplishment of a great object, which is worthy of your ambition. You are capable of completing it. My advice is pursue it, even if it should oblige you to live on bread and cheese."

The Analytical Engine was new in its concept and contained the essential elements of today's modern digital calculators, except Babbage tried to do mechanically what is done electronically today. Babbage's "mill" was similar in function to today's computer element; his "store" was to serve the same purpose as today's "memory unit."

The type of information to be put into the Analytical Engine was surprisingly similar to the input of the modern digital calculators. The input to Babbage's machine, used "two sets of cards, 

75 Babbage, H. P. op. cit., p. 341.


77 Babbage, C. Passages, op. cit., pp. 113-114.

the first to direct the nature of the operations to be performed - these are called operation cards: the other to direct the particular variables on which the cards are required to operate - these latter are called variable cards." Today, the modern digital calculators also require two similar inputs - the program and the data.

Part of Babbage's description of his Analytical Engine is as follows,

The Analytical Engine will possess a library of its own. Every set of cards once made will at any future time reproduce the calculations for which it was first arranged.

The tables to be used must, of course, be computed and punched on cards by the machine, in which case they would undoubtedly be correct... When the machine wanted a tabular number,...it would ring a bell and then stop itself. On this, the attendant would look at a certain part of the machine, and find that it wanted the logarithm of a given number, say of 2303. The attendant would then go to the drawer containing the pasteboard cards representing its table of logarithms. From amongst these he would take the required logarithmic card, and place it in the machine. Upon this the machine would first ascertain whether the assistant had or had not given him the correct logarithm of the number, if so, it would use it and continue its work. But, if the engine found the attendant had given him a wrong logarithm, it would then ring a louder bell, and stop itself. On the attendant again examining the engine, he would observe the words, 'wrong tabular number,' then discover that he really had given the wrong logarithm, and of course he would have it replaced by the right one.

78 Cont.

Babbage, C. Passages, op. cit., pp. 117 ff.

79 Ibid., pp. 117-118.


80 Ibid., pp. 119-120.
Babbage felt that with a machine such as his Analytical Engine, "the whole of the development and operations of analysis are now capable of being executed by machinery." He said, "As soon as an Analytical Engine exists, it will necessarily guide the future course of science."

Babbage's designs for the Analytical Engine were too grandiose for his time, but who is to say that the development of the modern electronic calculators has not proven him right in principle. For his work on the Analytical Engine, Babbage is justly known as the forefather of the modern digital calculator.

Ninth Bridgewater Treatise

Babbage still continued to participate in other activities. In May, 1837, he published his book The Ninth Bridgewater Treatise. This title means little to today's readers, but it was significant.

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81 Ibid., p. 136.
82 Ibid., p. 137.
to those of the 1830's. The first eight Bridgewater Treatises were brought about by the Earl of Bridgewater, upon his death, leaving a considerable sum of money to be distributed among eight distinguished authors who were chosen to write 'on the Power, Wisdom, and Goodness of God, as manifested in the Creation.' These eight books appeared between 1833 and 1837. Then, much to the surprise of everyone, the Ninth Bridgewater Treatise appeared from the self-invited, self-appointed Babbage.

Babbage said he wrote this treatise because the others had not carried their arguments far enough; and because Mr. Whewell, in the first treatise, had indicated that long application to mathematical and physical reasoning rendered one incompetent to make judgments about Natural Theology. Other factors which also probably induced Babbage to write the book were his desire to publicize his new Analytical Engine and the encouragement he had received from Dean S. J. MacLean of Dublin on his explanation of miracles.

The Ninth Bridgewater Treatise book was grand in its conception and much superior to many of the first eight Bridgewater Treatises, but in its execution it was "like many other of Babbage's works, a

85 Macfarlane, op. cit., pp. 77-78.
87 Macfarlane, op. cit., p. 78.
Littell's Living Age, op. cit., p. 584.
magnificent torso." However, in spite of the broken chapters, interrupted arguments, and typographical gaps, the book does show that the pursuit of mathematics can lead "to new views on the truth of natural theology." It demonstrated that the analysis used in the Analytical Engine could be used to prove the possibility of miracles. Babbage's reasoning on this subject, which was very original and ingenious, concluded that miracles "are not the breach of established laws, but they are the various circumstances that indicate the existence of far higher laws, which, at the appropriate times produce the preintended results."

The Ninth Bridgewater Treatise was well received and a second edition was published in 1838. In reference to Babbage's explanation of miracles it was said, "this view on miracles has been adopted by all the principle religious writers on the subject."

Railroads

A great growth had occurred in British railroads during the 1830's and Babbage "naturally took a great interest in the subject,

89 Macfarlane, op. cit., p. 78.

90 Loc. cit.


from its bearing upon mechanism as well as upon political economy."

In the late 1830's and early 1840's there raged in England the "battle of the gauges" for some railroads had adopted the broad gauge (6 feet), and some the narrow gauge (4 feet 8-1/2 inches). With the permission of the Directors of the Great Western Railway and at his own expense, Babbage, in 1838 and 1839, spent five months conducting a series of elaborate experiments on the merits of the broad gauge track. A Government commission, of which George Airy was a member, reported in favor of the narrow gauge, but "their recommendation was opposed effectively in Parliament by the broad gauge interest, supported by Babbage, who devised very ingenious instruments and made much more scientific observations than Airy." Babbage's testimony won the day for the broad gauge interests but, due to the number of other railroads using the narrow gauge, years later all British track was gradually unified at the narrow gauge.

The following reminiscence indicates how, at least in later life, Babbage acted with reference to one of his conclusions. "He thought it safer to travel as near the center of the train as might

93 Babbage, C. Passages, op. cit., p. 313.
94 Macfarlane, op. cit., p. 115.
95 Babbage, C. Passages, op. cit., Chapter XXV.
96 It is interesting to note the great similarity between Babbage's experiments and what is used on some American railroads today. Cf. Babbage, C. Passages, op. cit., pp. 320 ff. and "Electronic Track Tester." Business Week, November 22, 1952.
97 Macfarlane, op. cit., p. 115.
be; and he made it a rule to avoid the first and last carriages at any inconvenience. I remember being with him, when, on this account, he was almost obliged to give up going by an express train, although he would otherwise have had to wait some hours at the station."\(^{97}\)

Babbage's interest in railroading and other mechanical subjects was probably instrumental in his serving as President of the Physical and Mechanical Section of the British Association in 1838.\(^{98}\)

Besides acting as President of its statistical section, in 1835, Babbage served as trustee for the British Association from 1832 to 1838\(^{99}\) and attempted to develop a closer alliance between the British Association and the manufacturing and commercial interest, but this failed.\(^{100}\)

**Visit to Italy**

Due to the contacts Babbage made during his long stay in Italy, in 1828, as well as his international fame, Babbage was invited to attend a meeting of men of science in Italy in 1830.\(^{101}\) Babbage recorded little of the official meetings, but glowingly wrote of the

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97 "Recollections of Mr. Grote and Mr. Babbage." *Macmillan's Magazine*, XXVII, No. 162, April, 1873, p. 495.


100 See Chapter IV, "Exposition of 1851."

flattering reception he received from the King of Italy, Charles Albert.\textsuperscript{102} Babbage's last book, \textit{Passages From the Life of a Philosopher}, was dedicated to the King's son, in memory of his late father, to whom Babbage felt, "indebted for the first public and official acknowledgement of" the Analytical Engine.\textsuperscript{103}

It was as a result of Babbage's explanations of the Analytical Engine to some of the Italian notables that Count Menembra, former Prime Minister of Italy, wrote a description of the Analytical Engine.\textsuperscript{104} Later, the Countess of Lovelace, expert mathematician and daughter of poet Byron, translated this article and, at Babbage's suggestion, added extensive notes and published it.\textsuperscript{105} This translation and notes was the first English description of the Analytical Engine and stands today as one of its best.\textsuperscript{106}

Deciphering

Babbage found deciphering to be one of the most fascinating arts and was undoubtedly correct in his evaluation when he wrote,

\textsuperscript{102} \textit{Ibid.}, Chapter XXIV.
\textsuperscript{103} \textit{Ibid.}, "Dedication."
\textsuperscript{104} Babbage, C. \textit{Passages}, \textit{op. cit.}, pp. 130 ff.
\textsuperscript{105} Babbage, C. \textit{Exposition of 1851}, \textit{op. cit.}, p. 269.
\textsuperscript{106} Athenaeum, \textit{op. cit.}, p. 564.
\textsuperscript{105} Babbage, C. \textit{Passages}, \textit{op. cit.}, p. 136.
\textsuperscript{106} Reprinted in Babbage, Henry P. \textit{op. cit.}
\textsuperscript{106} Hartree, \textit{op. cit.}, pp. 69 ff.
"I fear I have wasted upon it more time than it deserves." To aid in deciphering, Babbage took a good English dictionary and had it copied into 26 other dictionaries, each containing words with the same number of letters; i.e., the first dictionary had words of only one letter, the next words of two letters, etc., through to words of 26 letters. A second set of dictionaries was then prepared containing all possible modifications of each word. Next, each dictionary was marked for all words with double letters. Following this, words were arranged alphabetically by second letters, then by third letters, etc. With all this, Babbage prided himself in being able to decipher almost anything and to work many word puzzles.

Although Babbage wrote an article on deciphering and engaged in a published exchange of letters with John H. B. Thwaites on the subject, there is no evidence to indicate that the time Babbage spent on the subject was of any practical use.

**Babbage's Ballet**

With all his other activities Babbage occasionally enjoyed attending the theatre and sometimes took bit parts in plays.

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109 Ibid., p. 495.
To add to the beauty of the scenes Babbage conceived the idea of using colored "spot lights" in the theatre. After much experimentation he developed oxy-hydrogen blowpipes and color filters which produced the desired effects.\textsuperscript{112} To show these to best advantage he then devised a "Rainbow Dance" and then, to use the dance, he wrote his ballet, \textit{Alethes and Iris}.\textsuperscript{113} The ballet was never produced, however, for the proprietor feared the oxy-hydrogen fires would burn the theatre down and "that if the house were burnt, his customers would also be burnt with it."\textsuperscript{114} Babbage considered this a "valid objection, for though he could have insured the building, he could not have insured his audience."\textsuperscript{115}

Abandonment of the Difference Engine

No construction had been done on the Difference Engine since 1833, but Babbage still had hopes. The Government had already spent about 17,000 pounds on the project but Babbage felt they should spend more.\textsuperscript{116} Much correspondence continued between Babbage and

\begin{itemize}
  \item \textsuperscript{112} \textit{Ibid.}, p. 254.
  \item \textsuperscript{113} \textit{Ibid.}, p. 255.
  \item Guest, Ivor "Babbage's Ballet." \textit{Ballet}, April, 1948, pp. 51-56.
  \item \textsuperscript{114} Babbage, C. \textit{Passages}, \textit{op. cit.}, p. 258.
  \item \textsuperscript{115} \textit{Loc. cit.}
  \item \textsuperscript{116} Weld, \textit{op. cit.}, p. 383.
\end{itemize}
the Government on this subject, and the subject was even taken up in Parliament. A review of these events, however, indicates that Babbage did not always choose the most opportune time to present his case and also did not always state it too well. Finally, in November, 1832, Mr. Goulburn, Chancellor of the Exchequer, wrote Babbage regretting that the expense necessary to put the Difference Engine in working condition so far exceeded what the Government would be justified in incurring that they had no alternative but to abandon the project. The Government offered to withdraw all claim to the machine, as already constructed, and place it entirely at Babbage's disposal. This offer Babbage declined and then interviewed Sir Robert Peel, First Lord of the Treasury, with the hope of receiving some consideration from the Government for the sacrifices he had already made on designing and supervising the construction of the Difference Engine. "The result of this interview was entirely unsatisfactory," to Babbage. Thus, the engagement which had existed

118 Loc. cit.
120 Ibid., pp. 94-95.
for 20 years between Babbage and the Government finally terminated, but Babbage still had hopes.

Babbage suspected that his enemies, George Airy and Richard Sheepshanks, were behind the Government's abandonment of the Difference Engine. These suspicions were years later confirmed when parts of George Airy's diary were published for, under the date of 1812, the following appeared, "On September 15, Mr. Goulburn, Chancellor of the Exchequer, asked my opinion on the utility of Babbage's calculating machine, and the propriety of spending further sums of money on it, I replied entering fully into the matter, and giving my opinion that it would be worthless." George Airy was the Astronomer Royal at that time and his views were listened to. It should be noted, however, that he was known not to be always an objective man, and in this case he certainly was not unbiased.

Not only had hard feelings existed between Babbage and Airy for years, but Airy probably did not forgive Babbage for proving him wrong during the railroad gauge disputes. It also should be noted

121 Babbage, C. Exposition of 1851, pp. 154 ff.


In light of this comment it is interesting to note that years earlier George Airy had thought enough of Babbage's idea to sketch a computing machine himself. Ref. Ibid., p. 37.


124 See Chapter III, "Babbage and South vs. Sheepshanks and Airy" and Chapter IV, "Railroads."
that the Chancellor of the Exchequer, Mr. Goulburn, may also have been biased against Babbage for Babbage had been campaign chairman of at least one of his political opponents.\footnote{See Chapter III, "Entry into Politics."}

Although Babbage had declined the Government's offered donation of the Difference Engine, he did purchase some of its parts.\footnote{Babbage, Henry P. \textit{op. cit.}, p. 196.} The portion already assembled was placed in the museum of King's College, London, in January, 1843, but not in the British Museum as Babbage had recommended.\footnote{Babbage, C. \textit{Passages}, \textit{op. cit.}, p. 94.} Of this portion it was said, "it is capable of calculating to five figures, and two orders of differences, and performs the work with absolute precision; but no portion whatever of printing machinery, which was one of the great objects in the construction of the engine, exists."\footnote{Weld, \textit{op. cit.}, p. 392.} It was far short of being able to calculate to 20 figures, and 6 orders of differences, as Babbage had hoped it would.\footnote{Babbage, C. \textit{Passages}, \textit{op. cit.}, p. 147.}

Babbage still did not give up the cause of the Difference Engine, for he turned over his papers and correspondence on the subject to Sir Harris Nicholas, who then summarized the events of the preceding 20 years.\footnote{\textit{Ibid.}, Chapter VI.} This resulting statement was then privately printed
and summarized in the *Philosophical Magazine* for September, 1843. These articles, however, did not elicit sufficient support to bring the Difference Engine out of the realm of a museum piece, but this was still not the last of the Difference Engine in Babbage's life.

**Difference Engine Number Two**

Babbage had started the design of his Analytical Engine in 1833, but it was not until 1848 that he mastered this project. He then resolved to complete the drawings for another Difference Engine, which would embody "all the improvements and simplifications which years of unweary study produced for the Analytical Engine." The drawings for the Difference Engine No. 2 were completed in 1849.

Meanwhile, Babbage tried to rally support for his project via Mr. Weld's review of his work in the eleventh chapter of *The History of the Royal Society*. This chapter was in turn reviewed, with added comments, by Professor DeMorgan in the *Athenæum*. Both of these articles were reprinted and circulated by Babbage but still

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133 Ibid., p. 105.


there was no Government support forthcoming.\textsuperscript{136}

In 1851 Babbage published the book, \textit{The Exposition of 1851},\textsuperscript{137} which, besides attacking some of the operations of that International Exposition, continued to put forth the cause of his calculating machines.\textsuperscript{138} This book may have achieved results; for in 1852, the Earl of Rosse, President of the Royal Society, offered to seek the assistance of Lord Derby, then Prime Minister.\textsuperscript{139} It was proposed to the Prime Minister that for Difference Engine No. 2, "The Government should apply to the President of the Institution of Civil Engineers to ascertain,

1st, Whether it was possible, from the drawings and notations, to make an estimate of the cost of constructing the engine?

2ndly. In case this question was answered in the affirmative - then, could a Mechanical Engineer be found who would undertake to construct it, and at what expense.\textsuperscript{140}

Babbage also submitted a letter to Lord Derby endorsing the above proposal, but the letter was certainly not humble in its tone. Among other things, Babbage indicated that although the Government has spent about 17,000 pounds on the first Difference Engine, he had "sacrificed upon this and other works of science upwards of 20,000

\textsuperscript{136} Babbage, C. \textit{Exposition of 1851}, op. cit., pp. 286.
\textsuperscript{137} Ibid.
\textsuperscript{138} See this chapter, "Exposition of 1851."
\textsuperscript{139} Babbage, C. \textit{Passages}, op. cit., pp. 97-98.
\textsuperscript{140} Ibid., p. 98.
Babbage said, "I desire only to discharge whatever imagined obligation may be supposed to rest upon me, in connection with the original undertaking of the Difference Engine; though I cannot but feel that whilst the public has already derived advantage from my labors, I have myself experienced only loss and neglect."²

Without consulting any engineers the prime minister turned the matter over to his Chancellor of the Exchequer, who replied "that Mr. Babbage's projects appear to be so indefinitely expensive, the ultimate success so problematical, and the expenditure certainly so large, that the Government would not be justified in taking upon itself any further liability." At this reply Babbage's wrath knew no bounds. He said, among other things, "the Herostratus of Science if he escaped, will be linked to the destroyer of the Ephesian Temple."⁴

(Although not mentioned by Babbage, one wonders if the renewed interest and publicity in the Difference Engine might not have been occasioned by the Government providing an annual grant of 1,000 pounds, to be administered by the Royal Society, for the promotion of scientific inquiries.)⁵

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² Ibid., p. 103.
³ Ibid., p. 106.
⁴ Ibid., p. 107.
⁵ Ibid., p. 111.
Tools

Babbage described himself as having "inveterate habit of contriving tools." Unfortunately, little precise description remains of his additions to the knowledge of tool making, but what does remain shows that he was an expert in this.

About 1846, Babbage wrote, "Paper on the Principles of Tools for Turning and Planing Metals." This short but instructive paper appeared as part of the appendix to Charles Holtzapffel's, Turning and Mechanical Manipulation, and was followed by a description of some of Babbage's cutting tools, tool holders, tool sharpening mechanisms, and safety devices. These articles show Babbage to be an expert in the design and use of tools. For example, he clearly stated the purpose of the various tool angles and the importance of a proper compromise in the angles used. He clearly expressed some of the forces involved in removing metal with tools and recognized the importance of using tool holders with inserted cutting tools. He also knew the utility of using a safety shield to protect the operator's eyes. His cutting bar was very similar to

1146 Babbage, C. Passages, op. cit., p. 2.


See photostat, Chapter VII.


1149 Holtzapffel, op. cit., II, pp. 983-991.
what is used today and was one of his tools which was manufactured and sold to the public.

Babbage's "face-cutter for the lathe," is the first example known to exist of not only a face-cutter but of an inserted tooth face-cutter. No face milling machine is known to have existed before this time; perhaps Babbage's face-cutter led to the design of today's modern face milling machines.

The holding devices designed for sharpening the cutting surfaces of this face-cutter indicated how well Babbage understood the problems of tool design and tool sharpening. His following summary statements show how thoroughly he was an expert on tools:

The tool holders should be so contrived as to have several cutters successively removing equal cuts - the cutting edge should be easily adjusted to the work. - the steel of which the cutters are formed should be of the best kind, and after it is once hardened, should never again be submitted to that process - The form and position of the cutter should be such that it may, when broken or blunted, be easily ground, having but one or at the utmost two faces requiring grinding. - It is desirable that when being ground it should be fixed into some temporary handle, in order that it may always be ground at the same cutting angles. - The cutters should be very securely, but also very simply tightened in their places.

Although there is no other known exact description of Babbage's


151 Holtzapffel, II, op. cit., p. 991.

152 Ibid., p. 987.
tools, there is evidence, such as the following, concerning his ability along these lines.

In 1829, the special committee of the Royal Society which investigated Babbage's work mentioned his problem, "of constructing, and in many cases inventing, tools and machinery, of great expense and complexity, (and in many instances of ingenious contrivances, and likely to prove useful for other purposes hereafter)..." 153

Weld, in 1848, said regarding Babbage's work,

a long series of experiments, have, however, been made upon the art of shaping metals; and the tools to be employed for that purpose have been discussed, and many drawings of them prepared. The great object of these inquiries in experiment is, on the one hand, by simplifying the construction as much as possible, and on the other, by contriving new and cheaper means of execution... 154

Babbage, in referring to his work on calculating machines wrote,

after examining all of the resources of existing workshops, I came to the conclusion that, in order to succeed, it would be necessary to advance the art of construction itself...

During the many years the construction of the Difference Engine was carried on, the following course was adopted. After each drawing had been made, a new inquiry was instituted to determine the mechanical means by which the several parts were to be formed. Frequently sketches, or new drawings, were made, for the purpose of constructing the tools or mechanical


154 Weld, op. cit., p. 391.
arrangements thus contrived. This process often elicited some simpler mode of construction, and thus the original contrivances were improved. In the meantime, many workmen of the highest skill were constantly employed in making the tools, and afterwards in using them for the construction of parts for the engine. 155

In this same book, The Exposition of 1851, Babbage wrote the following in connection with information which should be listed about the articles at the Exhibition.

Thus in cutting tools, as applied to various metals, it is very important that the angle at which the tool is applied should be stated: it is also necessary to state the angle which the edge of the tool receiving the shaving cut off, makes with the surface cut. The velocity of the tool in cutting should be stated, also the names of the fluids, if any, used in cutting. 156

The Earl of Rosse, a man known for his mechanical ability, 157 as President of the Royal Society said the following regarding Babbage's tools, "I may remark in passing, that the tools which were invented for the construction of the machine were afterwards found of utility...as some of our most eminent mechanical engineers readily testify." 158 Even following the very bitter attack on Babbage in 1851, Richard Sheepshanks said, "I have understood that, in the hands of Mr. Clement, the construction of the Calculating Machine formed a school of better workmanship than had hitherto existed.

156 Ibid., p. 114.
158 Babbage, C. Passages, op. cit., p. 102.
If it tended to develop the talents of Mr. Joseph Whitworth, the cost has been amply repaid." \(^{159}\)

Babbage’s son, in reviewing his father’s work said,

Among the workmen discharged by Clement on 10th April, 1833, was J. Whitworth (afterwards Sir J. Whitworth Bart). He and others saw in the Difference Engine on which they were daily employed the most exact workmanship; they saw many pieces made identically the same size to gauge; surfaces planed and turned accurately flat, screws (made from about 1827) with a fixed number of threads to the inch and tools which produced work not to be excelled in accuracy even at the present day. A lathe made to order in 1823-24 by Clement is on deposit loan in the South Kensington Museum. Its guide screws have divided circles on the handles, so that the tool can be set to the fraction of a thread; they are pivoted on a large divided circle, so that a cone of any angle can be turned, and two cutting tools can be set at once, so that with a little management two different diameters can be cut, one after the other, on piece after piece without shifting the tool, or touching the guide screw. Many other improved tools were also in use. \(^{160}\)

Dudley Buxton, in reviewing Babbage’s work in 1933 said, "his lathe (now preserved in the Science Museum) is remarkable for its anticipation of the work performed by modern machine tools and for the method of holding the tool... \(^{161}\)

To carry out much of his work, Babbage had hired his own draftsmen and workmen and had converted his coach house into a forge and foundry, and his stables into a workshop. \(^{162}\) The evidence presented

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\(^{159}\) Sheepshanks, op. cit., p. 92.

\(^{160}\) Babbage, Henry P. op. cit., p. 340.

\(^{161}\) Buxton, op. cit., p. 46.

\(^{162}\) Babbage, Passages, op. cit., p. 113.
here plus that in chapters VII and IX indicate that Babbage certainly made a contribution to the progress of manufacturing via his improvement of tools and machines.

Exposition of 1851

Much of Babbage's book, The Exposition of 1851; or Views of the Industry, the Science, and the Government of England, was written before the opening of this great International Exposition in London; but its publication was held up, for reasons unstated, until after the Exposition had closed. Babbage did not, however, suppress its publication as some of his friends had urged.

The book presents some of Babbage's views on England's industry, science and government; a good many of his opinions on the Exposition of 1851; plus opinions on his calculating machines, for he said, "it would have been affectation not to have mentioned the Calculating Engines." It is doubtful that this book brought much credit to Babbage for, although parts of it contained interesting ideas, the thoughts are too frequently discontinuous and too often the reader is impressed that these are the ramblings of a disappointed man. In the preface, for example, Babbage appeared to be answering those

163 Babbage, C. Exposition of 1851, op. cit.
164 Ibid., p. xiii.
165 Ibid., p. vii.
166 Ibid., p. viii.
who called him "crotchity," "impracticable," a "disappointed man," and a "cantankerous fellow." 167 He seemed to be giving his impression of himself when he wrote, "to move in any rank of society as an exception to such general rules, is a very difficult, and if accompanied by the consciousness of the situation, a very painful position to a reflecting mind." 168

The book appears to have been written because Babbage felt that he and science should have played a larger part in the Exposition and because Babbage wished to again call attention to various occurrences relating to the calculating machines. Among the latter, is a bitter attack on George Airy and Richard Sheepshanks for their unjust actions toward him and his machines. 169

The book is of interest to this study for several of the ideas it expressed. In the first chapter, when discussing methods of inquiry and investigation, Babbage included an explanation of what later became known as "the science of shoveling." 170 Babbage's comments on this are set forth in Chapter VII. Below is a brief review of some other ideas in The Exposition of 1851.

167 Ibid., p. ix-x.
168 Ibid., p. xi.
169 Ibid., Chapter XII.
170 Babbage, C. Exposition of 1851, op. cit., Chapter I.
On the importance of industry Babbage wrote,

The Triumph of the industrial arts will advance the cause of civilization more rapidly than its warmest advocates could have hoped, and contribute to the permanent prosperity and strength of the country, far more than the most splendid victories of successful war. The influences thus engendered, the arts thus developed, will long continue to shed their beneficial effects over countries more extensive than those which the sceptre of England rules.\textsuperscript{171}

On education Babbage said that those who admit to true principles

Must feel an earnest desire to support every effort which may assist in their dissemination amongst the masses of mankind. Education is the earliest, and the most effective aide; but it must be secular education. It must be the education of the faculties of each child, with reference to the wants of his future course of life. The religion of the uneducated and unenlightened man, even when true, partakes the nature of superstition, and instruction in religious truth alone will not be enough; his mind must be opened and informed on other subjects too.\textsuperscript{172}

Babbage had long been a champion of better and more practical education.\textsuperscript{173}

On scientific societies Babbage wrote,

Associations for occasional discussion, of men pursuing the same or similar studies, have long been found advantageous for the intercommunication of the difficulties, the doubts, and the discoveries of students. In more recent times, when each art has gradually connected itself with the sciences on which its success depends, the importance of

\textsuperscript{171} Ibid., pp. xii-xiii.
\textsuperscript{172} Ibid., p. 11.
\textsuperscript{173} See Chapter III, \textit{Decline of Science}. 
these meetings has become obvious to the manufacturer, although in this country it may not yet have become apparent to the statesman.174

Babbage mentioned some of the part he played in establishing various professional societies and referred to his proposal of having the British Association exhibit "the raw produce, the processes, and the instruments for the production of manufactured goods, to unite in the same common interest, not only the consumers, but all those who contributed to the production, or even the distribution of wealth."175

Babbage had strongly advocated that the British Association work for closer cooperation and interchange of ideas between the men of science and those of practical experience, but his proposals did not prevail. His 1839 public letter to the Members of the British Association had been unsuccessful in accomplishing this closer coordination between science and industry.176

In The Exposition of 1851 Babbage discussed how the French had promoted the arts of commerce and manufacturers by establishing the "Conservatoire des Arts et Metiers" in 1795, and how England had the Society of Arts, but it "has for years been languishing in premature decay." In France, professors helped industrial progress by lecturing

175 Ibid., p. 18.
"gratuitously on those sciences more immediately connected with arts and manufactures." Also, about every five years, France produced valuable expositions of national industry, to a good advantage. Now, at long last, England was attempting such by the exposition of 1851. Babbage followed this with many suggestions and criticisms on running the exposition, some of which were used in later expositions.

Babbage wanted the prices of all articles on exhibit to be shown, for "the low price of an article might prove that it had been manufactured in some mode entirely different from that usually practiced. This would lead to an examination of it, in order to discover the improved process." He also knew that "the price of an article compared to its weight, might prove that the metal of which it is made could not be genuine." It is of interest to note that some of Babbage's comments on price indicated that he had a much better comprehension of retailers' expenses than when he earlier feuded with the book sellers.

177 Ibid., pp. 22-25.
178 Ibid., pp. 26 ff.
179 Ibid., p. 81.
180 Loc. cit.
181 See Chapter IV, "Third Edition of Economy of Machinery and Manufactures."
In discussing prizes, Babbage suggested:

One of the inventions most important to a class of highly skilled workmen [engineers] would be a small motive power, -- ranging perhaps from the force of half a man to that of two horses, which might commence as well as cease its action at a moment's notice, require no expense of time for its management, and be of moderate price both in original cost and in daily expense.¹⁸³

Babbage certainly would have been an admirer of today's electric motors and portable power tools. On electric lights he noted, "the improvements which have been made in economy of making voltic batteries, lead to the expectation that they may be employed as sources of artificial light."¹⁸¹

Babbage indicated the importance of data on tools¹⁸⁵ and also suggested that samples and data about the products should be collected and the appropriate ones adopted as international standards.¹⁸⁶ His book then became very personal and covered such things as the actions which Messrs. Airy and Sheepshanks took against Babbage and South, circumstances involving the calculating machines, attacks on the press and political parties of England, etc.¹⁸⁷

The book concluded with an appendix consisting of Weld's and the

¹⁸³ Ibid., p. 103.
¹⁸⁴ Ibid., p. 114.
See preceding "Tools."
¹⁸⁵ Ibid., pp. 125 ff.
¹⁸⁶ Ibid., pp. 149 ff.
¹⁸⁷ Ibid., p. 253 ff.
Athenaeum's comments on Babbage's calculating machines, all of which appeared to have been an attempt to rally support for Babbage's calculating machines. 188

Open Feud With Sheepshanks

The feud of South and Babbage with Sheepshanks and Airy continued to boil into the open. Besides the earlier troubles mentioned in Chapter III; South and Sheepshanks engaged in a heated exchange of letters in The Times in 1838, during which Babbage was also attacked by Sheepshanks. 189 In 1847 Sheepshanks, in "A Reply to Mr. Babbage's letter to The Times," bitterly attacked Babbage for the comments he had made about Airy, etc. in his letter to The Times, "On the Planet Neptune and the Royal Astronomical Society's Medal." 190

In The Exposition of 1851 Babbage pointed out some of Sheepshanks' underhanded tactics 191 and then apparently encouraged South to publish a letter in the Mechanics Magazine which also reflected poorly on Sheepshanks. Babbage then sent copies of this letter to the Councils of the Royal Society and the Royal Astronomical Society with the hope that they would take action against Sheepshanks. 192

188 Babbage, C. Passages, op. cit., p. 1149.
189 Reprinted in Sheepshanks, op. cit., pp. 5-37, (preface).
191 Babbage, C. Exposition of 1851, op. cit., Chapter XII.
192 Sheepshanks, A Letter, op. cit., p. iii.
When this failed Babbage made similar charges against Sheepshanks at the June, 1853, meeting of the Board of Greenwich Visitors. Sheepshanks admitted illegally bringing into the country "a foreign instrument without payment of duty;" but he denied the other charges and in a 92-page pamphlet, devastatingly attacked Babbage. This pamphlet ruthlessly reviewed and attacked many of Babbage's past mistakes and indiscretions and placed many of Babbage's actions in a very poor light, all of which must have dealt a severe blow to Babbage's already declining reputation.

It may have been as a result of all this publicity that Charles Dickens based the character of Daniel Doyce on the life and work of Charles Babbage.

Continuation of the Calculating Machines

Babbage never ceased promoting his calculating machines. In 1847 he had hoped that the portion of the Difference Engine in the King's College Museum would be used as an attraction at an exhibition in Dublin, but it wasn't. In 1851 he had wanted it to be exhibited at the Great International Exhibition in London, but the Commissioners were insensible to "the greatest intellectual triumph of their country." A few years later, an exhibition in New York had wanted to display it but the request to the British Government for its loan was unsuccessful. In 1855, the great French exhibition
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occurred and, although the English exhibit was deficient in 'instruments de precision,' to Babbage's disappointment "neither did the Royal Society advise, nor the government propose, to exhibit the Difference Engine." 195 There was, however, at this French exhibition, a difference engine made by Messrs. Scheutz of Sweden which did receive high honors. 196

The Scheutz difference engine was related to Babbage's work, for it was after reading Dr. Lardner's explanation of Babbage's Difference Engine in the Edinburgh Review of 1834 that "Mr. George Scheutz, at that time the editor of a technological Journal at Stockholm, was so fascinated with the subject that he set about constructing a machine for the same purpose as that of Mr. Babbage, namely, that of calculating and simultaneously printing numerical tables." 197 For many years, George Scheutz and his son worked hard on their machine and, after many difficulties, finally produced a successful one in 1853. The machine calculated in numbers up to 16 figures and printed 8 of these in lead, at the rate of 25 calculations per minute. 198 When this machine was exhibited in England it was anticipated that Babbage would not give it a friendly welcome. 199

195 Babbage, C. Passages, op. cit., pp. 149-150.


198 Babbage, Henry P. op. cit., p. 1440.

199 Loc. cit.

Babbage, Charles "Observations addressed to the President and Fellows of the Royal Society on the Award of their Medals for 1856." Ref. Babbage, C. Passages, op. cit., p. 496.
but, to the contrary, Babbage praised it and recommended that its inventors be given one of the Medals of the Royal Society. Babbage used a description of the Scheutz engine as a vehicle to explain the virtues of his own mechanical notation.\textsuperscript{200}

Babbage felt that when his mechanical notation became generally known, he had little doubt that it would be adopted as the ordinary language for all machinery; because by its means, even the most complicated mechanism could be easily understood, without the aid of any written description. The signs themselves expressed everything without difficulty. As proof of this, he might state, that he had, at various periods, at least half a dozen draftsmen working for him, who, after a short time, had each been able to use it with facility.\textsuperscript{201}

A duplicate of the Scheutz machine was made in England and used to compute the English life tables of 1864 and the original machine, which was purchased by the Dudley Observatory at Albany, New York, was used to print a few other tables.\textsuperscript{202} These machines were very similar to Babbage's proposed Difference Engine, but not his Analytical Engine. Their successful completion showed that a difference engine could be successfully produced, but the limited use which was made of them also showed that they did not have the world-shaking results that Babbage had always predicted.

After the success of the Scheutz difference engine at the French Exhibition, the unfinished Babbage Difference Engine finally was

\begin{footnotes}
\item[201] Babbage, Henry P. \textit{op. cit.}, p. 441.
\item[202] Babbage, C. \textit{Passages, op. cit.}, pp. 150 ff.
\end{footnotes}
displayed at the London Exhibition of 1862. This was brought about through the effort of Mr. Gravatt, a friend of Babbage's and co-worker with Brunel on the Thames Tunnel. Babbage was pleased that his Difference Engine was displayed, but he was very dissatisfied with its location and the way the commissioners did not give it nearly as much space and attention as he had suggested. He wrote in detail of this in his book, Passages From the Life of a Philosopher. At the exposition Babbage sometimes gave lectures on the Difference Engine, but after a few hecklings on his opinions of organ grinders, he ceased this undertaking.

Babbage continued to work on the design of his Analytical Engine until his death in 1871, and then others tried to continue from where he had left off. In 1878 a "British Association Committee endeavored to make something of his plans, but reported that they were not sufficient to put into the hands of a draftsman." In 1888 Babbage's youngest son, Major-General Henry P. Babbage, 

203 Loc. cit.

Brunel, Isambard The Life of Isambard Kingdom Brunel, Civil Engineer. London: Longman, Green, and Co., 1870, Chapter I.

204 Babbage, C. Passages, op. cit., Chapter X.

205 Ibid., pp. 165-166.

See "Street Nuisances" Chapter IV.

206 Buxton, op. cit., p. 50.

read a paper on the Analytical Engine and in 1889 published, Babbage's Calculating Engine; being a Collection of Papers Relating to them, their History and Construction. This book, which is mostly reprints of previous articles, had apparently been started by Charles Babbage but finished by his son. Henry Babbage had faith in his father's machines and continued to work on them until 1915. By 1906 he had succeeded in constructing the "mill" of the Analytical Engine and printed some tables, but he died in 1918 at the age of 94 without completing the construction of the Analytical Engine.

The portions of the Babbage's calculating machines continued to be exhibited at events such as the following: Exhibition of Scientific Apparatus, 1876; British-Japan Exhibition, 1910; Coronation Exhibition, 1911.

207 Hartree, op. cit., p. 69.
208 Babbage, Henry P. op. cit.
209 Babbage, C. Passages, op. cit., p. 496.
210 Buxton, op. cit., p. 60.
211 Hartree, op. cit., pp. 70-71.
212 Macfarland, op. cit., p. 77.
In 1933 Mr. Dudley Buxton reviewed some of his original papers but found that since "Babbage was always changing his mind and improving his ideas, his notation is very difficult to follow at this interval of time." 214

The extent of Babbage's influence on the designers of other calculating machines is not known, but it is known that at least a few besides Messrs. Scheutz studied and admired his work. 215 Although others built difference engines, it was not until the 1940's that machines were built to operate on the scale conceived for the Analytical Engine and these were very similar in many principles to the Analytical Engine. 216

Street Nuisances

The last 20 years of Charles Babbage's life must have been very disheartening ones, for he not only failed in some of his most cherished ventures, but during these latter years he was pitifully plagued by street noises and nuisances of all sorts. 217 During the years since 1828, when Babbage first moved to Manchester Square, the district had changed from a quiet residential section to one with hackney coach stands, coffee shops, beer shops, and lodging

214 Buxton, op. cit., p. 147.
216 Hartree, op. cit., pp. 55 ff.
217 Babbage, C. Passages, op. cit., Chapter XXVI.
houses. The noises which accompanied this change grew too much for Babbage, and he frequently tried to suppress them, with little success. Babbage saw his fight with the street noise makers as a crusade for he said, "I am quite aware that I am fighting the battle of everyone of my countrymen who gains his subsistence by his intellectual labour...On careful retrospect of the last dozen years of my life, I have arrived at the conclusion that I speak within limit when I state that one-fourth part of my working power has been destroyed by the nuisances against which I have protested." In his meticulous fashion Babbage kept records of the "instruments of torture permitted by the government to be in daily and nightly use in the streets of London." He listed them in the following order of annoyance: organs, brass bands, fiddle, harps, harpsichords, hurdy-gurdies, flageolets, drums, bag pipes, etc. He likewise tabulated the "Encouragers of Street Music." Babbage frequently sent his servants out to chase the noise makers away, and when this failed he went out himself. If the trouble maker still persisted, he started after a policeman to suppress the trouble. These tactics became such a source of amusement to the neighbors that Babbage was frequently followed by a noisy mob of

218 Manchester Square may have been the original of Dickens' Bleeding Heart Yard, the place where Daniel Royce had his factory. Ref. Dickens, Little Dorrit, op. cit., pp. 131, 143.


220 Ibid., p. 338.
of heckling children as he sought the police. 221

Babbage prosecuted some of the noise makers in court, but they came faster than he could prosecute and his actions usually made them even more desirous of annoying him, often with the encouragement and payment from his neighbors. The courts eventually stopped prosecuting the offenders and Babbage suffered further by many broken windows, dead cats, and other offensive material being thrown into his area. Babbage procured the service of lawyers, protested to the Home Office, and wrote letters on the subject to the London Times, but to no avail. 222 His attacks on the street musicians became widely known and made him the laughing stock of much of London. 223 Some suggested he organize a society to put a stop to the street nuisances, but he said he had no time for this. 224 These noises were apparently a source of great annoyance to him until he died, for in his last book he wrote in much detail of this continuing problem, and, although he did not seem to realize it, he made himself appear to be quite a ridiculous old man.

Passages from the Life of a Philosopher

Babbage’s last book was published in 1861, when he was 71 years

221 Ibid., pp. 346 ff.
222 Ibid., Chapter XXVI

223 "Recreations of a Philosopher." Harper’s New Monthly Magazine, New York: XXX, No. 175, December, 1861, p. 34.
of age. It is not an autobiography but is the best single source of information about his varied career. He stated the purpose of the book as follows:

The remarkable circumstances attending these calculating machines, of which I have spent so large a portion of my life, make me wish to place on record, some account of their past history. As, however, such a work would be utterly uninteresting to the greater part of my countrymen, I thought it might be rendered less unpalatable by relating some of my experiences amongst various classes of society, widely differing from each other, in which I have occasionally mixed.225

Some of his chapters are only a slight reworking and others a straight republishing of previous writings.226 The book frequently related a variety of isolated circumstances in which Babbage took part—"some of them arranged in order of time, and others grouped together, in separate chapters, for similarity of subject."227

Some portions of the book are amusing and some instructive; other portions are boring with too much detail of the calculating machines. It would be superfluous to add a lengthy review of this book for much of the details of Chapters II, III, and IV of this dissertation were pieced together from the ramblings of the Passages from the Life of a Philosopher.

The book does show that Babbage had a sense of humor, but it also shows that he was inclined to be biased in presenting

225 Ibid., pp. vii-viii.
226 Ibid., Chapters VI, XXII, etc.
227 Ibid., p. viii.
information relating to himself. Babbage said that the selection of material for the book "has been made in some cases from the importance of the matter. In others, from the celebrity of the persons concerned; whilst several of them furnish interesting illustrations of human character." Little did Babbage realize that this book showed him to be the most interesting character of them all.

Other Writings and Activities of Later Life

The circumstances already stated in this chapter show that Babbage continued to indulge in many diversified activities during the last half of his life. Some of his other activities of this period are indicated below.

Although not a member of the Geological Society, Babbage frequently attended their meetings and presented papers such as the following: "Observations on the Temple of Serapis, at Pozzuoli, near Naples, with remarks on certain causes which may produce Geological Cycles of great extent," Some Impressions in

228 Loc. cit.


On astronomical subjects and the presentation of medals Babbage wrote a few comments in the following short pieces: "On the Application of a Camera Lucida to a Telescope," 235 "On the Planet Neptune," 236 and "Note respecting the pink projections from the


Sun's disk observed during the total eclipse in 1851. He also wrote, "Note on the Boracic Acid Works in Tuscany," "Laws of Mechanical Notation," "On Submarine Navigation," "On a Method of Laying Guns in a Battery without exposing the men to the shot of the enemy," "Table of the Relative Frequency of Occurrence of the Causes of Breaking Plate-glass Windows," and "Statistics of Clearing-Houses." This last article was an interesting analysis of bank clearings and causes of their fluctuations.


239 "Laws of Mechanical Notation, with Lithographic Plate." Privately printed for distribution, July 1851, Ref. Babbage, C. Passages, op. cit., p. 496.


241 "On a Method of Laying Guns in a Battery without exposing the men to the shot of the enemy." The Times, 8 August, 1855, Ref. Babbage, C. Passages, op. cit., p. 496. Note: A search of the London Times for this date did not reveal the above article.


Babbage, in April, 1835, turned his attention to assist his friend Herschel, then at the Cape of Good Hope, in carrying out over the whole world, on certain days, a system of meteorological observations. These days, which were called term-days, were the 21st of December, 21st of March, 21st of June, and 21st of September. At these times continued observations were to be made at every hour, commencing at noon on the days above mentioned and terminating the next day at the same hour. These observations, in the introduction of which Mr. Babbage took an active part, were continued in Europe, America, India, and Africa, and led finally to the establishment of the various systems of simultaneous weather-reports of the present day.\textsuperscript{244}

In 1856 Babbage reprinted a pamphlet he had written in 1833, "Observations on Peerage for Life,"\textsuperscript{245} It contained Babbage's views on how to expand the House of Lords by creating non-hereditary peerages on the basis of merit for the life of the person.\textsuperscript{246} His "Thoughts on the Principles of Taxation, with reference to a Property Tax and its Exceptions"\textsuperscript{247} went through four editions and made an interesting reference to "a fair day's wage for a fair day's work."\textsuperscript{248} Since this phrase became common in later industrial management literature the reference is quoted in Chapter VII.

\textsuperscript{244} "Charles Babbage," \textit{Annual Report of Smithsonian Institution}, op. cit., p. 184.


\textsuperscript{246} \textit{Ibid.}

\textsuperscript{247} Babbage, Charles "Thoughts on the Principles of Taxation, with reference to a Property Tax, and its Exceptions." London: John Murray, 1848, 1851, 1852, 1907.

\textsuperscript{248} \textit{Ibid.}, 1848, p. 20.

See also Babbage, C. \textit{Passages}, op. cit., p. 439.
In the 1850's Babbage became very interested in experimenting with occulting lights for lighthouses, i.e., lights which would enable each lighthouse to blink its own code number. He wrote his ideas on the subject in "Note respecting Lighthouses" and sent it to many governments. The Congress of the United States thought enough of the plan to grant $5,000 for experimentation, following which it was recommended for adoption and Babbage was invited to the United States to supervise the experiments. Babbage had always admired the United States and wished to make the visit but felt he did not have the time to make the trip. Fortunately he did not go, for the ship on which he would have traveled sank during the crossing of the Atlantic.

Babbage said that English lighthouses adopted his system but, "such was the state of the Government of the country with respect to scientific matters, he understood the Government had adopted the

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250 Loc. cit.
252 Babbage, C. Exposition of 1851, op. cit., p. vi.
principle without the slightest acknowledgement of it in any way whatever."  

From his work on lighthouses Babbage also devised means of using night signals and sun signals to transmit messages in times of war or peace.  

Another invention of Babbage's was the ophthalmoscope, an instrument to look into the interior of the eye.

Babbage also spent time on devising automatons to play games of skill, such as the game of "tit-tat-to." However, after inquiring as to the possibilities of earning money with such a machine, he gave up the venture as unprofitable. It was said, "He subsequently constructed an automatic chess player." There is no further evidence that this statement is true, but he did realize that it was possible to make a machine to successfully play an excellent game of chess. A century later the famous mathematician Norbert Wiener confirmed this possibility.

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258 Buxton, op. cit., p. 48.
In 1839 Babbage resigned his Lucasian Professorship, presumably to have more time to devote to his calculating machines.\(^{261}\) Always, however, he seemed to perpetually be seeking a position of recognition from the Government. For example, in a post-election banquet, following his defeat in the Finsbury Campaign, Babbage said, "In whatever position he might be placed, he should be desirous of promoting the interest of manufactures of the country."\(^{262}\) When the Government abandoned the Difference Engine, Babbage unsuccessfully sought a Government appointment in recognition of the work he had done.\(^{263}\) Babbage wrote that he tried several times to be appointed to each of the following positions but with no success: Registrar-General of Births, Deaths and Marriages; Mastership of the Mint; and Commissioner of Railways.\(^{264}\) The only position he seemed to have filled was a member of a committee to prevent forgery of banknotes.\(^{265}\) He was reported to have "refused more than one highly desirable position and profitable situation, in order that he might give his whole time and thoughts" in order to finish his Difference Engine.\(^{266}\)

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\(^{261}\) Babbage, C. Passages, op. cit., p. 31.  
\(^{262}\) The Times. London: No. 15,041, Friday, December 31, 1832.  
\(^{263}\) Babbage, C. Passages, op. cit., pp. 94 ff.  
\(^{264}\) Ibid., pp. 477 ff.  
\(^{265}\) Ibid., pp. 421 ff.  
\(^{266}\) Ibid., p. 96.
Richard Sheepshanks' following criticism of Babbage seemed to be too correct, "the objects of Mr. Babbage's cravings are -- titles, pensions, stars, red ribbons, institutions..."  

End of a Career  

Lord Moulton tells of the following visit to Babbage in his later years.

One of the sad memories of my life is a visit to the celebrated mathematician and inventor, Mr. Babbage. He took me through his work rooms. In the first room I saw the parts of the original Calculating Machine, which had been shown in an incomplete state many years before and had even been put to some use. I asked him about its present form. 'I have not finished it because in working at it I came on the idea of my Analytical Machine, which would do all that it was capable of doing and much more. Indeed, the idea was so much simpler that it would have taken more work to complete the Calculating Machine than to design and construct the other in its entirety, so I turned my attention to the Analytical Machine.' After a few minutes talk we went into the next work room, where he showed and explained to me the working of the elements of the Analytical Machine. I asked if I could see it. 'I have never completed it,' he said, 'because I hit upon an idea of doing the same thing by a different and far more effective method, and this rendered it useless to proceed on the old lines.' Then we went into the third room. There lay scattered bits of mechanism, but I saw no trace of any working machine. Very cautiously I approached the subject, and received the dreaded answer, 'It is not constructed yet, but I am working at it, and it will take less time to construct it altogether than it would have taken to complete the Analytical Machine from the stage in which I left it.' I took leave of the old man with a heavy heart. When he died a few years later, not only had he constructed no machine but the verdict of a jury of kind and sympathetic scientific men who were deputed to pronounce upon what he had left behind him,

267 Sheepshanks, op. cit., p. 70.
either in papers or mechanism, was that everything was too incomplete to be capable of being put to any useful purpose. 268

In his later years Babbage "used to speak as if he hated mankind in general, England in particular, and the English Government and organ-grinders most of all. Yet, paradoxical as it may seem, there was something harmless, and even kindly, in his misanthropy; for (always except the musicians) he hated mankind rather than man..." 269 He is reported to have said "that during the many long years he had lived alone, he had never known a happy day." 270

His vivacity was considerably moderated and the mortification which he felt on account of not being able to complete his calculating machine, and the loss of friends, cast a shadow over his latter days. 271

Towards the end of his life Babbage's mind seemed to be clear on his calculating machines but otherwise began to fail him badly. He sometimes started out to visit old friends but forgot what he was going to do and had to return home again. 272 "He regretted the


270 Ibid., p. 495.


272 Buxton, op. cit., p. 45.

M. L. op. cit., p. 58.
loss of memory, since with it was the loss of personal identity."  

On Friday, October 20, 1871, Babbage died at his home on Dorset Street, five months after the death of his great friend, John Herschel. As the London Times said, "in spite of the organ-grinder persecutors" he had lived to almost eighty years of age. He was buried in Kensal Green Cemetery, Harrow Road, just two and one-half miles from the Paddington Station of the Great Western Railroad. For those who are curious they may find his brain "pickled" and preserved at the Hunterian Museum of the Royal College of Surgeons, or described, with pictures, by Sir Victor Horsley in the Philosophical Transactions of the Royal Society.

Babbage had often wished that he could have given up the latter portion of his life in exchange for being able to live three days,

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276 "The Late Mr. Charles Babbage, F. R. S." The Times, London: No. 27,201, Monday, October 23, 1871, p. 3.
278 Buxton, op. cit., p. 63.
500 years hence with a scientific cicerone to explain the discoveries which had taken place since his death. 280 "He judged that the progress to be recorded would be immense; for, as he said, science tends to go on, not merely with a great, but with a constantly increasing rapidity." 281 Babbage died a lonely and disappointed man, without even an obituary notice by the Royal Society. 282 In spite of his many failures and shortcomings, Babbage contributed more to the advancement of mankind than most men who have been "great successes."

Chapter Summary

At forty years of age Babbage was internationally famous for his writings, the Difference Engine, and his scientific activities. Besides traveling in the best European scientific circles, Babbage's house was one of the social centers of London. Many prominent persons of London and abroad who had either intellect, beauty, or rank, were frequent visitors at his famous Saturday evening soirées.

There is no doubt that Babbage was an unusual person. He was a leader of ideas and a champion of causes. However, as an instigator

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280 Tollemache, op. cit., p. 495.

281 Loc. cit.

282 "Obituary Notices of Fellows Deceased." op. cit. This omission may have been George Airy's parting blow to Babbage, for he was President of the Royal Society in 1872 and may have been the cause of this omission.
of various organized groups, he seldom became their full leader. Babbage had a great diversity of interests and frequently he openly sought support and recognition for his projects. He often sought honors for which others did not judge him qualified.

Babbage was painfully sensitive about other peoples opinion of him and reportedly collected everything printed about him, posting the pros and cons in parallel columns. Babbage's great anxiety about the success and fame of his Difference Engine caused his countenance to frequently be one of sadness and strain.

Various writers made comments on Babbage's character, but one of the most surprising references appeared in Charles Dickens novel *Little Dorrit*. In this novel of 1857, the characteristics of Daniel Doyce were based on the life and works of Babbage.

During the first forty years of his life Babbage gained great fame. During the last forty years he still added accomplishments, but at a decreasing rate and his inherited fortune was largely spent on his projects.

In 1832 Babbage had helped establish the British Association for the Advancement of Science and in 1833 he helped found the Statistical Section of this association. This was followed by his founding the Statistical Society of London in 1834. Since Cambridge days, one of Babbage's main ideas was to collect, compile, and more usably present data to be used to further knowledge. The Analytical Society, the book on life assurance societies, the improved logarithm tables, the
emphasis on constants of nature and art, the promotion of statistical societies, the inductive emphasis of *On the Economy of Machinery and Manufactures*, and other projects were all aimed at achieving this objective. Even the Difference Engine was being constructed for the purpose of making better and more usable data available to science. Babbage believed that knowledge was power and saw many opportunities to further the knowledge of mankind.

In 1833 events occurred which changed the future course of Babbage's life. This year construction on the Difference Engine was stopped due to financial difficulties and Babbage's desire to have the construction moved to a new workshop near his home. After much delay, the partially completed work was removed from Clement's workshops, where for ten years many precision tools and machines had been made and skilled workmen trained on the novel construction of the Difference Engine. One of those who had been working on the Difference Engine was Joseph Whitworth, soon to become one of England's leading mechanical engineers.

Meanwhile, Babbage had invented a new calculating machine, the Analytical Engine. Due, however, to confusion as to Babbage's intention, frequent changes in government, and other occurrences, Babbage did not receive further support for his project from the Government. Babbage continued to design, experiment, and construct parts in his own workshop and at his own expense, but his failure to complete a calculating machine brought him much criticism.
The Analytical Engine, though never completed, was the forefather of the modern digital computer. It included the input of data and programs on punch cards, a computer element, a memory unit, and internal self-correction mechanisms. Babbage felt that all operations in analysis could be executed by machinery and would thus guide the future course of science.

Babbage still participated in other activities. In 1837, he published a book, fragmentary in nature, on religion. This Ninth Bridgewater Treatise was good enough to include an explanation of miracles which was used for many years thereafter. In the late 1830's Babbage also made a series of elaborate experiments on the proper gauge of railroad tracks. In 1840 he went on a triumphal tour of Italy and was well received for his work on the Analytical Engine. In his own country, however, he was unsuccessful in obtaining government support for his project and finally in 1842 they gave up all claim to his Difference Engine. It now became a museum piece.

Babbage still did not give up hope, and designed Difference Engine No. 2. When, in the 1850's the Government still refused to support the project, Babbage's wrath knew no bounds.

Babbage, however, still carried on various other activities. He spent much time on his hobby of deciphering and produced various dictionaries for it. To carry out his ideas of theatre lighting he wrote a ballet. In 1856 he produced an excellent "Paper on the Principles of Tools for Turning and Planing Metals." This, plus
other evidence, indicated Babbage was an excellent machinist and undoubtedly did much to advance the art of manufacturing, as discussed in Chapter IX.

Babbage's Exposition of 1851; or Views of the Industry, the Science, and the Government of England was very personal in parts and, besides publicizing his calculating machine, seemed to be answering those who called him crotchety, impracticable, a disappointed man, and a contankerous fellow. This book, however, had several interesting sections; one of which outlined how a frequently repeated process, like shoveling, could be studied and improved by eliminating waste movements and reducing fatigue. This outlined the science of shoveling for which F. W. Taylor later took great credit. (See Chapters VII, VIII, and IX.)

The above book also made a personal attack on Babbage's arch-enemy, Richard Sheepshanks. To this Sheepshanks made a lengthy, bitter attack on Babbage which certainly must have damaged Babbage's already declining reputation.

In a pamphlet on taxes Babbage wrote of a fair day's wage for a fair day's work.

Until his death Babbage continued to promote his calculating machine. His son, Henry Prevost Babbage, joined in attempting to promote and construct one, but as late as 1915 the son too was unable to complete one. In 1855, however, Messrs. Scheutz of Sweden did complete a difference engine largely based on an earlier description of Babbage's machine. This machine did receive wide recognition but
was of little practical use and did not bring about the great changes Babbage had predicted.

There were other activities and a great variety of articles in the latter part of Babbage's life, but his last twenty years must have been miserable for he was lonely, disheartened, and pitifully plagued by street noise-makers with whom he continually feuded. For these latter actions he became the laughing stock of much of London.

Babbage's last book, *Passages from the Life of a Philosopher*, was published in 1864, when Babbage was 71 years of age. Part of the purpose of the book was to "furnish interesting illustrations of human character." Little did Babbage realize that the book showed him to be the most interesting character of them all.

On Friday, October 20, 1871, Babbage died at his home on Dorset Street, at almost eighty years of age. In spite of his many failures and shortcomings, he had contributed much to the advancement of mankind.
CHAPTER V

ON THE ECONOMY OF MACHINERY AND MANUFACTURES,

SECTION I

Introduction

As explained in Chapter III, Charles Babbage's book, On the Economy of Machinery and Manufactures, contained the majority of his industrial management concepts and was an expansion of his earlier essay "Introductory View of the Principles of Manufactures." Both works were divided into two parts, with the first part devoted to "the mechanical part of the subject" and the second part to "a discussion of many of the questions which relate to the political economy of the subject." The following review of this book is similarly divided, with Section I covered in this chapter and Section II in the succeeding chapter.

Section I was the smaller of the two sections; contained fewer ideas important to this study; and underwent very few changes from the


2 Babbage, Charles "Introductory View of the Principles of Manufactures." Encyclopedia Metropolitana; or Universal Dictionary of Knowledge, VIII, London: B. Fellows, et al., 1845, pp. 1-84. Note: The above copy was used for reference because of its availability. This volume was originally published in 1829.


4 Ibid., p. 2.
time the material first appeared in the introductory essay. The only significant changes in this part occurred in the first edition with the inclusion of an introduction and more illustrative examples, plus the moving of the contents of chapter 12 from the conclusion of the introductory essay to the end of Section I. This latter was probably done in order to enable the book to be concluded with the chapter, "On the Future Prospects of Manufactures, as Connected with Science."

Method of Presentation

The presentation of the material in the next two chapters is based on the fourth and last edition of the book, with changes of content from the earlier works being noted in the footnotes. For completeness the main ideas of each chapter are reviewed but for brevity much of the excellent illustrative material is regrettably condensed or omitted. In order to preserve accuracy, Babbage's own words are frequently used in presenting main ideas or those important to the history of management concepts. The appropriate page references, to the fourth edition, are noted after each chapter or subject heading instead of in footnotes in order to relieve the review of an undue amount of footnoting. Chapter and subject headings which follow are given essentially as they appeared in the fourth edition.

Introduction to On the Economy of Machinery and Manufactures (pp. 1-2)\(^5\)

The object of the present volume is to point out the effects and the advantages which arise from the use of tools and

\(^5\) Two-page introduction added in first edition.
machines; - to endeavour to classify their modes of action; - and to trace both the causes and the consequences of applying machinery to supersede the skill and power of the human arm.

A view of the mechanical part of the subject will, in the first instance, occupy our attention, and to this the first section of the work will be devoted. The first chapter of the section will contain some remarks on the general sources from whence the advantages of machinery are derived, and the succeeding nine chapters will contain a detailed examination of principles of a less general character. The eleventh chapter contains numerous subdivisions, and is important from the extensive classification it affords of the arts in which copying is so largely employed. The twelfth chapter, which completes the first section, contains a few suggestions for the assistance of those who propose visiting manufactories.

Chapter I - Sources of the Advantages Arising From Machinery and Manufacturers (pp. 3-20)

England is distinguished from other countries by the perfection "to which we have carried the contrivance of tools and machines for forming those conveniences of which so large a quantity is consumed by almost every class of the community." England's manufacturing is not only important to herself but to other sections of the world and has continued to grow in importance in recent years. It is of vast importance to the well-being of this country that the interests of its manufacturers are well understood and attended to.

The advantages which are derived from machinery and manufactures seem to arise principally from three sources: The addition which they make to human power. -- The economy they produce of human time. -- The conversion of substances apparently common and worthless into valuable products."

Additions to Human Power (pp. 6-8) - Man adds power not only by adopting the forces derived from wind, water, and steam, but also by
continually improving his knowledge and by continually making new tools. "At each increase of knowledge as well as on the contrivance of every new tool, human labor becomes abridged." As evidence of this, note the improvements which man has made through the years in the moving of heavy objects.

The Economy of Human Time (pp. 8-11) -

The economy of human time is the next advantage of machinery in manufactures. So extensive and important is this effect, that we might, if we were inclined to generalize, embrace almost all of the advantages under this single head; but the elucidation of principles of less extent will contribute more readily to a knowledge of the subject.

Examples of saving time are the use of gun powder to blast rocks, speaking tubes to carry information, and a tool holder to hold a diamond at the proper angle when cutting glass.

Employment of Materials of Little Value (pp. 11-12) - The third advantage of machinery and manufactures is the conversion of apparently worthless items into valuable products. Examples of this are the products made from horse hoofs and worn out kitchen ware.

Tools (pp. 12-16) - To distinguish between a tool and a machine it may be said that "A tool is usually more simple than a machine; it is generally used with the hand when a machine is frequently moved by animal or steam power. The simpler machines are often merely one or more tools placed in a frame and acted on by a moving power." An example of using a simple tool to advantage is the small sheet iron tray used to arrange the pins during pin making. "If a cheap and
expeditious method had not been devised, the expense of manufacture would have been considerably enhanced."

Various operations occur in the arts in which the assistance of an additional hand would be a great convenience to the workman, and in these cases tools or machines of the simplest structure come to our aid: vises of different forms, in which the material to be wrought is firmly grasped by screws are of this kind, and are used in almost every workshop: but a more striking example may be found in the trade of the nail-maker. Much time is saved by the nail-maker for he works with both hands and a foot treadle. This last operates on the up stroke as well as on the down stroke. "Without this substitution of his foot for another hand, the workman would, probably be obliged to" take much more time in the operation.

Division of the Objects of Machinery (pp. 11-20) - Machinery may be classed as two types.

1st. Those which are employed to produce power; and as,
2dly. Those which are intended to merely transmit force and execute work. The first of these divisions is of great importance and is very limited in the variety of its species, although some of these species consist of numerous individuals."

There are mechanical agents which transmit power, such as: the lever, the pulley, and the wedge but no power is gained by their use. "Whatever force is applied at one point can only be exerted at some other diminished by friction and other incidental causes." "Whatever is gained in the rapidity of exertion is compensated by the necessity of exerting additional force."

Wind mills and water wheels do not create power in themselves but merely change the direction of natural forces already in motion. Even
in the case of steam, no power is created.

It is almost certain that the power necessary to produce it would at least equal that which was generated by the original combustion. Man, therefore, does not create power; but availing himself of his knowledge of nature's mysteries, he applies his talents to diverting a small and limited portion of her energies to his own wants; and, whether he employs the regulated action of steam, or the more rapid and tremendous effects of gunpowder, he is only producing on a small scale compositions and decompositions which nature is incessantly at work in reversing, for the restoration of that equilibrium which we cannot doubt is constantly maintained throughout even the remotest limits of our system. The operations of man participate in the character of their author; they are diminutive, but energetic during the short period of their existence; whilst those of nature, acting over vast spaces, and unlimited by time, are ever pursuing their silent and relentless career.

There is, it is true, a limit beyond which it is impossible to reduce the power necessary to produce any given effect, but it very seldom happens that the methods first employed at all approach that limit.

Chapter II - Accumulating Power (pp. 21-26)

Whenever the work to be done requires more force for its execution than can be generated in the time necessary for its completion, recourse must be had to some mechanical method of preserving and condensing a part of the power exerted previously to the commencement of the process. This is most frequently accomplished by a flywheel...

Another mode of accumulating power arises from lifting a weight and then allowing it to fall.

"Though not strictly in illustration of the subject discussed in this chapter," the subjects of guns and gunpowder is of interest. Various explosive phenomena may be explained by the fact, "That every force requires time to produce its effect."  

6 Discussion of guns added in second edition.
Chapter III - Regulating Power (pp. 27-29)

"Uniformity and steadiness in the rate at which machinery works, are essential both for its effect and its duration." Many types of governors are used to accomplish the regulation of power. The governor of the steam engine is one example. Regulating the supply of fuel to the fire under the boilers of the steam engine is another example.

Chapter IV - Increase and Diminution of Velocity (pp. 30-37)

The fatigue produced on the muscles of the human frame does not altogether depend on the actual force employed in each effort but partly on the frequency with which it is exerted. The exertion necessary to accomplish every operation consists of two parts: one of these is the expenditure of force which is necessary to drive the tool or instrument; and the other is the effort required for the motion of some limb of the animal producing the action. In driving a nail into a piece of wood, one of these is lifting the hammer, and propelling its head against the nail; the other is, raising the arm itself and moving it in order to use the hammer. If the weight of the hammer is considerable the former part will cause the greatest portion of the exertion. If the hammer is light the exertion of raising the arm will produce the greatest part of the fatigue. It does therefore happen, that operations requiring very trifling force, if frequently repeated, will tire more effectually than more laborious work. There is also a degree of rapidity beyond which the action of the muscles cannot be pressed.

The most advantageous load for a porter who carries wood upstairs on his shoulders has been investigated by M. Coulomb; but he found from experiment that a man walking upstairs without any load, and raising his burden by means of his own weight in descending, could do as much work in one day as four men employed in the ordinary way with the most favorable load.

The proportion between the velocity with which men or animals move and the weights they carry is a manner of considerable importance, particularly in military affairs. It is also of great importance for the economy of labor, to adjust the weight of that part of the animal's body which is moved, the weight of the tool it urges and the frequency of repetition of these efforts, so as to produce the greatest effect.

7 Two topics combined in second edition.
Sometimes a savings of time can be achieved "by making the same motion of the arm execute two operations instead of one."

"Whenever the work itself is light, it becomes necessary, in order to economize time, to increase the velocity." An example of this is the common spinning wheel.

In "the larger and more important machines the economy arising from the increase of velocity becomes more striking." Examples of this are the increased velocities designed into the various tilt-hammers which are used in many manufacturing operations.

"The most frequent reason for employing contrivances for diminishing velocity arises from the necessity of overcoming great resistances with small power."

Chapter V - Extending the Time of Action of Forces (pp. 38-39)

An example of extending the time of action of forces is by using wound-up spring mechanisms or ones operated by a slowly descending heavy weight.

Chapter VI - Saving Time in Natural Operations (pp. 40-46)

Time can be saved in various operations by either chemical or mechanical means. Examples are tanning, bleaching linen, and breaking up rocks in a river channel.

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8 In the introductory essay this topic was headed, "Spreading the Action of a Force Erected for a few minutes over a Large Time."
"It requires some skill and a considerable apparatus to enable many men to exert their whole force at a given point; and when this number amounts to hundreds or to thousands, additional difficulties present themselves." As far back as the Egyptians, sound signals have been used to coordinate the activities of men working in unison.

"In all our large manufactories numerous instances occur of the application of the power of steam to overcome resistances which it would require far greater expense to surmount by means of animal labor." Besides steam, hydraulic presses and shrink fitting of rivets are used to exert great forces.

"Whenever the individual operation demanding little force for its own performance is to be multiplied in almost endless repetition, commensurate power is required." Thus steam power is often applied to a number of highly repetitive operations, such as in weaving.

Machinery can sometimes execute operations too delicate for human touch, as in the case of separating powders into various degrees of fineness or removing unwanted fine filaments from woven cloth.

Chapter VIII - Registering Operations (pp. 54-61)

"One great advantage which we may derive from machinery is from the check it affords against the inattention, the idleness or the dishonesty of human agents. Few occupations are more worrisome than

9 Two topics combined in first edition.
counting a series of repetitions of the same fact..." Some of the devices which are used do the following: count the number of strokes of a steam engine, measure the length of yard goods produced, check on the vigilance of a watchman, measure the quantity of gas consumed, and automatically register experimental data.

The sale of water by the different companies in London, might also, with advantage, be regulated by a meter. If such a system were adopted much water which is now allowed to run to waste would be saved and an unjust inequality between the rates charged on different houses by the same company would be avoided.

An apparatus has recently been applied to watches by which the hand which indicates seconds leaves a small dot of ink on the dial plate whenever a certain stop or detent is pushed in. Thus, whilst the eye is attentively fixed on the phenomena to be observed, the finger registers on the face of the watch dial the commencement and the end of its appearance.10

Chapter IX - Economy of the Materials Employed (pp. 62-65)

"The precision with which all operations by machinery are executed, and the exact similarity of the articles thus made produces a degree of economy in the consumption of the raw material which is, in some cases, of great importance." Such savings in raw materials are brought about by the recent improvements made in cutting wood veneer and by improvements in printing press operations.

10 See also Chapter III, "Decline of Science" and Chapter VII, "The Art of Observing."

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Chapter X - The Identity of the Work When it is of The Same Kind, and Its Accuracy When of Different Kinds (pp. 66-68)\textsuperscript{11}

"Nothing is more remarkable, and yet less unexpected, than the perfect identity of things manufactured by the same tool." Examples of this are the like products produced by the proper setting of stops on a lathe, or the use of dies and punches.

The accuracy with which machinery executes its work is, perhaps, one of its most important advantages: it may, however, be contended, that a considerable portion of this advantage may be resolved into a saving of time; for it generally happens, that any improvement in tools increases the quantity of work done in a given time. Without tools, that is, by the mere efforts of the human hand, there are, undoubtedly, multitudes of things which it would be impossible to make. Add to the human hand the rudest cutting instrument and its powers are enlarged: the fabrication of many things then becomes easy and that of others possible with great labor.

One of the most difficult things to produce is a straight line or a plane surface for "if two surfaces are worked against each other, whatever may have been their figure at the commencement, there exists a tendency in them both to become portions of spheres."

Chapter XI - Copying (pp. 69-113)

All modes of action of machinery can be classed under the general topic of copying,

...taken in its most extensive sense. Almost unlimited pains are in some instances, bestowed on the original, from which a series of copies is to be produced: and the larger the number of these copies, the more care and pains can the manufacturer afford to lavish on the individual. It may thus

\textsuperscript{11} Two topics combined in first edition.
happen, that the instrument or tool actually producing the work shall cost five or even ten thousand times the price of each individual specimen of its power.

The following classification of means of copying "is not offered as a complete list; and the explanations are restricted to the shortest possible detail which is consistent with a due regard to making the subject intelligible."

Printing From Cavities (pp. 70-73)\(^\text{12}\)

The art of printing, in all its numerous departments, is essentially an art of copying. The methods of printing are as follows: copper plate printing, engravings on steel, music printing, calico printing from cylinders, and printing from perforated sheets of metal or stenciling.

Printing From Surface (pp. 73-80)\(^\text{13}\)

"This second department of printing is of more frequent application in the arts than that which has just been considered." It consists of printing from wooden blocks, printing from movable types, printing from stereotypes, lettering blocks, calico printing from blocks, printing oilcloth, letter copying, printing of china, lithographic printing and register printing.

Copying by Casting (pp. 81-85)

"The art of casting, by pouring substances in a fluid state into

\(^{12}\) Subheading added in first edition.

\(^{13}\) Subheading added in first edition.
a mold which retains them until they become solid, is essentially an
art of copying." Iron and other metals, plaster, and wax can all be
cast. Various techniques can be used, of which some give a very high
degree of precision.

Copying by Molding (pp. 85-93)

This method of producing multitudes of individuals having
an exact resemblance to each other in external shape is adopted
very widely in the arts. The substances employed are, either
naturally or by artificial preparation, in a soft or plastic
state. They are then compressed by mechanical force, sometimes
assisted by heat, into a mold of the required form.

Items which may be made by molding are bricks, tiles, embossed
china, glass seals, square glass bottles, wooden snuff boxes, horn
knife handles and umbrella handles, molded tortoise shell, tobacco
pipes, embossing upon calico, embossing upon leather, swaging, engraving
by pressure, gold and silver molding, and ornamental papers.

Copying by Stamping (pp. 94-95)

This mode of copying is extensively employed in the arts.
It is generally executed by means of large presses worked with
a screw and heavy fly wheel. The materials on which the copies
are impressed are most frequently metals, and the process is
sometimes executed when they are hot, and in one case when the
metal is in the state between solidity and fluidity.

Coins and metals, ornaments for military accoutrements and furniture,
buttons and nail heads, and the clichée process are all done by
stamping.

Copying by Punching (pp. 95-97)

This mode of copying consists in driving a steel punch
through the substance to be cut, either by blow or by pressure.
In some cases the object is to copy the aperture, and the substance separated from the plate is rejected; in other cases the small pieces cut out are the objects of the workman's labor.

Examples of copying by punching are punching iron plates for boilers, punching tin iron, cards for guns, ornaments of gilt paper, and steel chains.

Copying by Elongation (pp. 98-100)

"In this species of copying there exists but little resemblance between the copy and the original. It is the cross section only of the thing produced which is similar to the tool through which it passes." This process if used for wire drawing, leaden pipes, iron rolling, and vermicelli.

Copying With Altered Dimensions (pp. 100-113)

These means of copying are pentagraph, turning, rose engine-turning, copying dies, shoe-last making, copying busts, screw-cutting, printing from copper-plates with altered dimensions, engraving from medals, and making lace by caterpillars.

"This enumeration, which is far from complete, of the arts in which copying is the foundation, may be terminated with an example which has long been under the eye of the reader;" the means of copying which have been necessary to bring On the Economy of Machinery and Manufactures about.

"The mysteries, however, of an author's copying form no part of our inquiry, although it may be fairly remarked, that in numerous instances, the mental far eclipses the mechanical copyist."
Having now reviewed the mechanical principles which regulate the successful application of mechanical science to great establishments for the production of manufactured goods, it remains for us to suggest a few inquiries and to offer a few observations, to those whom an enlightened curiosity may lead to examine the factories of this or of other countries.

The remark, — that it is important to commit to writing all information as soon as possible after it is received, especially when numbers are concerned, — applies to almost all inquiries. It is frequently impossible to do this at the time of visiting an establishment, although not the slightest jealousy may exist; the mere act of writing information as it is communicated orally is a great interruption to the examination of machinery. In such cases, therefore, it is advisable to have prepared beforehand the questions to be asked and to leave blanks what answers which may be quickly inserted, as, in a multitude of cases, they are merely numbers. Those who have not tried this plan will be surprised at the quantity of information which may, through its means, be acquired, even by a short examination. Each manufacture requires its own list of questions, which will be better drawn up after the first visit. The following outline, which is very generally applicable, may suffice for an illustration; and to save time, it may be convenient to have it printed; and to bind up, in the form of a pocket book, a hundred copies of the skeleton forms for processes, with about twenty of the general inquiries.

GENERAL INQUIRIES.

Outlines of a Description of any of the Mechanical Arts ought to contain information on the following points.

Brief sketch of its history, particularly the date of its invention, and of its introduction into England.

Short reference to the previous stages through which the material employed has passed; the places whence it is procured; the price of a given quantity.

The various processes must now be described successively according to the plan which will be given in § 161; after

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14 Chapter XII quoted in full. This chapter is practically a verbatim quote of the "Conclusion" of the introductory essay. The only significant change was the addition of the quote from M. Coulomb in the first edition.
which the following information could be given.

Are various kinds of the same article made in one establishment, or at different ones, and are there differences in the processes?

To what defects are the goods liable?

What substitutes or adulterations are used?

What waste is allowed by the master?

What tests are there of the goodness of the manufactured articles?

The weight of a given quantity, or number, and a comparison with that of the raw material?

The wholesale price at the manufactory? £ s. d. per

The usual retail price? £ s. d.

Who provide tools? Master, or men? Who repair tools? Master, or men?

What is the expense of the machinery?

What is the annual wear and tear, and what its duration?

Is there any particular trade for making it? Where?

Is it made and repaired at the manufactory?

In any manufactory visited, state the number ( ) of processes; and of the persons employed in each process; and the quantity of manufactured produce.

What quantity is made annually in Great Britain?

Is the capital invested in manufactories large or small?

Mention the principal seats of this manufacture in England; and if it flourishes abroad, the places where it is established.

The duty, excise, or bounty, if any, should be stated, and any alterations in past years; and also the amount exported or imported for a series of years.
Whether the same article, but of superior, equal, or inferior make, is imported?

Does the manufacturer export, or sell, to a middleman, who supplies the merchant?

To what countries is it chiefly sent? — and in what goods are the returns made?

Each process requires a separate skeleton, and the following outline will be sufficient for many different manufactories:

<table>
<thead>
<tr>
<th>Process</th>
<th>Manufacture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place</td>
<td>Name</td>
</tr>
<tr>
<td>date</td>
<td>183</td>
</tr>
</tbody>
</table>

The mode of executing it, with sketches of the tools or machine if necessary.

The number of persons necessary to attend the machine.

Are the operatives men, women, or children? If mixed, what are the proportions?

What is the pay of each? (s. d.) (s. d.) (s. d.) per hour?

What number of hours do they work per day?

Is it usual, or necessary, to work night and day without stopping?

Is the labour performed by piece or by day-work?

Who provide tools? Master, or men? Who repair tools? Master, or men?

What degree of skill is required, and how many years' apprenticeship?

The number of times the operation is repeated per day or per hour?

The number of failures in a thousand?

Whether the workmen or the master loses by the broken or damaged articles?
What is done with them?

If the same process if repeated several times, state the diminution or increase of measure, and the loss, if any, at each repetition.

In this skeleton, the answers to the questions are in some cases printed, as 'Who repair the tools? — Masters, Men;' in order that the proper answer may be underlined with a pencil. In filling up the answers which require numbers, some care should be taken: for instance, if the observer stands with his watch in his hand before a person heading a pin, the workmen will almost certainly increase his speed, and the estimate will be too large. A much better average will result from inquiring what quantity is considered a fair day's work. When this cannot be ascertained, the number of operations performed in a given time may frequently be counted when the workman is quite unconscious that any person is observing him. Thus the sound made by the motion of a loom may enable the observer to count the number of strokes per minute, even though he is outside the building in which it is contained. M. Coulomb, who had great experience in making such observations, cautions those who may repeat his experiments against being deceived by such circumstances: — 'Je prie' (says he) 'ceux qui voudront le repeter, s'ils n'ont pas le temps de mesurer les resultats apres plusieurs jours d'un travail continu, d'observer les ouvriers a differentes reprises dans la journée, sans qu'ils sachent qu'ils sont observés. L'on ne peut trop avertir combien l'on risque de se tromper en claculant, soit la vitesse, soit le temps effectif du travail, d'apres une observation de quelques minutes.'—Mémoires de l'Institut. Tom. II. p. 247. It frequently happens, that in a series of answers to such questions, there are some which, although given directly, may also be deduced by a short calculation from others that are given or known; and advantage should always be taken of these verifications, in order to confirm the accuracy of the statements; or, in case they are discordant, to correct the apparent anomalies. In putting lists of questions into the hands of a person undertaking to give information upon any subject, it is in some cases desirable to have an estimate of the soundness of his judgment. The questions can frequently be so shaped, that some of them may indirectly depend on others; and one or two may be inserted whose answers can be obtained by other methods: nor is this process without its advantages in enabling us to determine the value of our own judgment. The habit of forming an estimate of the magnitude of any object
or the frequency of any occurrence, immediately previous to our applying to it measure or number, tends materially to fix the attention and to improve the judgment."

Evolution of Section I

This completes the review of Section I of "On the Economy of Machinery and Manufactures." Except for the moving of the material on the methods of observing factories from the end of the book to the end of Section I, there was no significant change in the content of Section I from the time it first appeared in the essay, "Introductory View of the Principle of Manufactures." Even the material on observing factories was verbatim from the introductory essay except for an added quote from M. Coulomb.

The changes in Section I involved only slight changes in wordings or sentence structure, an occasional combining of two subjects into one heading, and added illustrations to the ideas already stated. These slight changes occurred almost entirely in either the first or second edition. This almost static condition of Section I did not hold, however, for Section II, as noted in the following chapter. Thus, Babbage developed the introductory essay into the book by expanding the second portion of the work.

Chapter Summary

The first section of the On the Economy of Machinery and Manufactures deals with the mechanical principles of the subject. The material covered in this section is almost identical with that in the introductory essay to the Encyclopedia Metropolitana, "Introductory
The only significant changes in this section of the work were the addition of a two-page introduction, the addition of more illustrations to the principles already stated, and moving of the chapter on the method of observing factories from the end of the work to the end of Section I. A summary of main ideas of Section I follows.

In England manufacturing is of growing importance and it is for the best interests of the country that its manufactures are well understood and attended to.

The advantages which are derived from machinery and manufactures arise principally from three sources: The addition which they make to human power, the economy they produce of human time, and the conversion of substances apparently common and worthless into valuable products.

Tools and machines are important to manufacturers. A tool is usually more simple than a machine, and it is generally used with a hand while a machine is frequently moved by animal or steam power. The simpler machines are often merely one or more tools placed in a frame and acted on by moving power. Many tools or simple machines can be used to aid the workman or enable him to substitute his foot for another hand, as in the case of a foot-operated vise.

Machinery is of two types. First, those which are employed to produce the power; and secondly, those which are intended to merely transmit force and execute work. It is important to be able to produce power, but power cannot be created. It can only be converted
from one form to another, as in windmills or steam engines.

Some of the uses to which machinery is put are as follows:
accumulating power, regulating power, increasing and diminishing
velocity, extending the time of action of forces, saving time in
natural operations, exerting forces too great for human power, execut­
ing operations too delicate for human touch, registering operations,
economizing on the materials employed, and producing identical or
accurate work.

In increasing and diminishing velocity the fatigue of man depends
not only on actual force employed but on the frequency of its exertion.
The exertion consists of that force necessary to drive the tool plus
that force necessary to move the bodily parts causing the movement.
This is explained with an example of hammering and a reference to the
work of M. Coulomb in observing porters carrying loads upstairs.

The proportion between the velocity with which men or animals
move and the weights they carry is of considerable importance. Also
for the economy of labour it is important to adjust the weight of the
bodily part moved, the weight of the tool, and the frequency of
operation, so as to produce the greatest effect.

The registering of operations is useful to check against inatten­
tion, idleness, or dishonesty. Also registering may be used to meter
various items or to time an operation while observing it.

The modes of action of machinery can be classed broadly under
the general term of copying. When there are a large number of copies
to be made the manufacturer can afford to lavish a great deal of
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pains on the original. Means of copying are as follows: printing from cavities, printing from surface, casting, molding, stamping, punching, elongation, and copying with altered dimensions. These are explained and illustrated. There are other modes such as those used by an author, which sometimes far eclipses the mechanical copyist.

For those desiring to observe and study factories, it is important to commit to writing all information as soon as possible after it is received, especially when numbers are concerned. In observing factories this can be accomplished by preparing beforehand questions to be asked with blank spaces for short answers. Many excellent sample questions are presented for making both general inquiries and inquiries on specific processes. Care should be taken to obtain the correct information and avoid such things as an operator increasing his speed when an observer stands before him with his watch in his hand to time the operation. Better answers may be obtained by learning what is a fair day's work or timing an operation when the worker is unconscious of being observed. M. Coulomb also warns about making correct observations. Answers should be verified by cross checking against each other or other known facts.
Introduction

The second section of *On the Economy of Machinery and Manufactures* was larger than the first section, underwent more changes, and contained more industrial management concepts. The following presentation of its contents is in the same manner as in the preceding chapter, i.e., the text is based on the fourth and last edition with significant changes in content from the earlier works being noted in footnotes. Babbage's own words are used in presenting his main ideas and those important to the history of management concepts. His excellent illustrative material is regretfully greatly condensed or omitted.

The chapter and subject headings are given as they appeared in the fourth edition with page references after each, instead of footnoted.

The second section, after an introductory chapter on the difference between making and manufacturing, will contain, in the succeeding chapters, a discussion of many of the questions which relate to the political economy of the subject. It was found that the domestic arrangement, or interior economy of factories, was so interwoven with the more general questions, that it was deemed unadvisable to separate the two subjects. The concluding chapter of this section, and of the work itself, relates to the future prospects of manufactures, as arising from the application of science.¹ ²


² Above paragraph added to first edition as part of the Introduction.
Chapter XIII - Distinction Between Making and Manufacturing (pp. 119-122)

The economical principles which regulate the application of machinery, and which govern the interior of all our great factories, are quite as essential to the prosperity of a great commercial country as are those mechanical principles, the operations of which have been illustrated in the preceding section.

The first object of every person who attempts to make any article of consumption, is, or ought to be, to produce it in a perfect form; but in order to secure to himself the greatest and most permanent profit, he must endeavour, by every means in his power, to render the new luxury or want which he has created, cheap to those who consume it. The large number of purchasers thus obtained will, in some measure, secure him from the caprices of fashion, whilst it furnishes a far greater amount of profit, although the contribution of each individual is diminished. The importance of collecting data, for the purpose of enabling the manufacturer to ascertain how many additional customers he will acquire by a given reduction in price of the article he makes, cannot be too strongly pressed upon the attention of those who employ themselves in statistical inquiries. In some ranks of society, no diminution of price can bring forward a great additional number of customers; whilst, among other classes, a very small reduction will so enlarge the sale, as to yield a considerable increase of profit.

Some of the government reports provide data on the number of persons who possess incomes of different amount and other personal finance data which could be tabulated and "such a table, formed even approximately, and exhibited in the form of a curve, might be of a service."  

3 The "Introduction" to the second part of the introductory essay constituted much of this chapter.

4 The importance of collecting statistical data was added in the first edition.

5 The suggestion of collecting these data from the Government reports and tabulating them as a curve was added in the second edition.
A considerable difference exists between the terms making and manufacturing. The former refers to the production of a small, the latter to that of a very large number of individuals. If, therefore, the maker of an article wish to become a manufacturer, in the most extended sense of the term, he must attend to other principles besides those mechanical ones on which the successful execution of his work depends; and he must carefully arrange the whole system of his factory in such a manner, that the article he sells to the public may be produced at as small a cost as possible.

In a highly civilized country competition will compel one to attend to the principles of the domestic economy of manufactures. Competition will drive a manufacturer to seek a savings in the expense of some of his processes. The benefits of such improvements will accrue to him for a short time but when sufficient experience has proved their value, they will become generally adopted, "until in their turn, they are superseded by other more economical methods."

Chapter XIV - Of Money as a Medium of Exchange (pp. 123-133)

Money has grown out of the barter system and, in civilized countries, sovereign powers have assumed the right of coinage. The decimal system of coinage is most usable, and England should consider shifting to it.

6 This distinction added in first edition.

7 This chapter was added in the second edition of On The Economy of Machinery and Manufactures. Of the three chapters added in the second edition, it is the only one which contains entirely new material. The chapter is a very good discussion of money as a medium of exchange, but since it is only indirectly related to manufacturing, it is summarized here.
Manufactured commodities become measured by the standards of coinage. "But it must be observed that the value of gold is itself variable; and that, like all other commodities, its price depends on the extent of the demand compared with that of the supply."

As transactions multiply, the use of bank notes, backed by gold, comes into frequent use. As commercial transactions increase further, checks replace the use of many bank notes and the clearing house then comes into being to perform its important function. Further progress could be made if all the private banks would keep accounts with the Bank of England.

For the general welfare of the community, the fluctuations in the value of money should be rendered as small and as gradual as possible. Sudden changes in the value of money work injustices, as shown by the examples of a widow living on an annuity, a worker building a machine to be paid for out of savings, and a worker building one on credit. The importance of preserving the value of the currency "as far as possible, unaltered in value, cannot be too strongly impressed upon all classes of the community."

Chapter XV - The Influence of Verification on Price (pp. 134-146)

The money price of an article at any given period is usually stated to depend upon the proportion between the supply and the demand. The average price of the same article during a long period, is said to depend, ultimately, on the power of producing and selling it with the ordinary profits of capital.

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8 Separated from the topic, "Of the Effects of Great Capitals employed in Manufactures" in the first edition.
But these principles, although true in their general sense, are yet so often modified by the influence of others, that it becomes necessary to examine a little into the disturbing forces. 9

The following factor, "though often of little importance, is, in many cases, of great consequence. The cost, to the purchaser, is the price he pays for any article, added to the cost of verifying the fact of its having that degree of goodness for which he contracts. In some cases, the goodness of the article is evident on mere inspection" and in other cases it is not. An item will be most uniform in price when its goodness is easy to determine; and when the goodness of an item is difficult to determine, it may have a great variety of prices. Sometimes fraudulent and bad articles destroy the reputation of an entire trade as shown by various examples. In other trades, such as the apothecary trade, one pays primarily not for the product but for reliability. Sometimes "the impossibility of verifying has, in a great measure, counteracted the beneficial effects of competition." 10 For with some articles, "it is impossible for the purchaser to verify at the time of purchase, or even afterwards, without defacing them." 11

The principle that price, at any moment, is dependent on the relation of the supply to the demand, is true to the full extent only when the whole supply is in the hands of a very large number of small holders, and the demand is caused by the wants of another set of persons, each of whom requires only a very small quantity. And the reason appears to be, and that

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9 Last qualifying sentence added in first edition.
10 Added in the first edition.
11 Added in the second edition.
it is only in such circumstances that a uniform average can be struck between the feelings, the passions, the prejudices, the opinions, and the knowledge of both parties.12

The problem of verification of price in postal deliveries is so great that it is recommended the government take over such operations.

It is important, if possible, always to connect the name of the workman with the work he has executed: this secures for him the credit or blame he may justly deserve; and diminishes, in some cases, the necessity of verification.13

If the commodity itself is of a perishable nature,... then time will supply the place of competition; and whether the article is in the possession of one or many persons, it will scarcely reach a monopoly price.

The effect of the equalization of price by an increased number of dealers, may be observed in the price of the various securities sold at the Stock Exchange. The number of persons who deal in 3 per cent stock being large, any one desirous of selling can always dispose of his stock at one-eighth per cent under the market price; but those who wish to dispose of bank stock, or any other securities of more limited circulation, are obliged to make a sacrifice of eight or ten times this amount upon each hundred pounds value.14

Chapter XVI - The Influence of Durability on Price (pp. 147-151)15

Having now considered the circumstances that modify what may be called the monetary amount of price, we must next examine a principle which seems to have an effect on its permanent average. The durability of any commodity influences its cost in a permanent manner. We have already stated that what may be called the monetary price of any commodity depends

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12 Paragraph added in first edition.
13 Paragraph added in second edition.
14 Example of stock market added in second edition.
15 Separated from the topic "Duration of Machinery" in the first edition.
upon the proportion existing between the supply and demand, and also upon the cost of verification. The average price, during a long period, will depend upon the labor required for producing and bringing it to market, as well as upon the average supply and demand; but it will also be influenced by the durability of the article manufactured.

It is evident that the average price of those things which are consumed in the act of using them, can never be less than that of the labor of bringing them to market. They may for a short time be sold for less, but under such circumstances, their production must soon cease altogether. On the other hand, if an article never wears out, its price may continue permanently below the cost of the labor expended in producing it; and the only consequence will be, that no further production will take place: its price will continue to be regulated by the relation of the supply to the demand; and should that at any after time rise, for a considerable period, above the cost of production, it will again be produced.

Articles become old from actual decay, or the wearing out of their parts; from improved modes of constructing them; or from changes in their form and fashion, required by the varying taste of the age. Thus a taste for luxuries is propagated downward in society; and, after a short period, the numbers who have acquired new wants become sufficient to excite the ingenuity of the manufacturer to reduce the cost of supplying them, whilst he is himself benefited by the extended scale of demand.

Chapter XVII - Price as Measured by Money (pp. 152-162)

The money price at which an article sells furnishes us with comparatively little information respecting its value, if we compare distant intervals of time and different countries; for gold and silver, in which price is usually measured, are themselves subject, like all other commodities, to changes in value; nor is there any standard to which these variations can be referred. The average price of a certain quality of different manufactured articles, or of raw produce, has been suggested as a standard; but a new difficulty then presents itself; for the improved method of producing such articles render their money price extremely variable within very limited periods.

16 The material of this chapter was an addition to the first edition.
Various quoted statistics substantiate this.

I cannot omit availing myself of this opportunity of calling the attention of the manufacturers, merchants, and factors in all our manufacturing and commercial towns, to the great importance, both for their own interests, and for that of the population to which their capital gives employment, of collecting with care such averages from the actual sales registered in their books. Nor, perhaps, would it be without its use to suggest, that such averages would be still more valuable if collected from as many different quarters as possible; that the quantity of the goods from which they are deduced, together with the greatest deviations from the mean, ought to be given; and that if a small committee were to undertake the task, it would give great additional weight to the information. Political economists have been reproached with too small a use of facts, and too large an employment of theory. If facts are wanting, let it be remembered that the closet-philosopher is unfortunately too little acquainted with the admirable arrangements of the factory; and that no class of persons can supply so readily, and with so little sacrifice of time, the data on which all the reasonings of political economists are founded, as the merchant and the manufacturer; and unquestionably, to no class are the deductions to which they give rise so important. Nor let it be feared that erroneous deductions may be made from such recorded facts: the errors which arise from the absence of facts are far more numerous and more durable than those which result from unsound reasoning respecting true data.

Various statistics are quoted showing variations in price over a period of years. "...it is clear that neither any one substance, nor even the combination of all manufactured goods, can furnish us with an invariable unit by which to form our scale of estimations.

Mr. Malthus has proposed for this purpose to consider a day's labour of an agricultural labourer," but this is not a satisfactory measure.

Chapter XVIII - Raw Materials (pp. 163-168)^17

Although the cost of any article may be reduced in its

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17 The first quoted paragraph was part of the topic, "Positions of Factories" in the introductory essay. The statistics, not quoted, were added in the first edition.
ultimate analysis to the quantity of labour by which it was produced; yet it is usual, in a certain state of the manufacturer of most substances, to call them by the term raw material...it becomes an interesting subject to trace the various proportions in which raw material, in this sense of the term, and labour unite to constitute the value of many of the productions of the arts.

Many statistics are quoted which show the price of the raw material relative to the price of the finished product.

Chapter XIX - The Division of Labour (pp. 169-190)

Perhaps the most important principle on which the economy of manufacture depends, is the division of labour amongst the persons who perform the work...The various principles on which the advantages of this system depend, have been much the subject of discussion amongst writers on Political Economy; but the relative importance of their influence does not appear, in all cases, to have been estimated with sufficient precision. It is my intention, in the first instance, to state shortly these principles, and then to point out what appears to me to have been omitted by those who have previously treated the subject.

1. Of the time required for learning. -- It will readily be admitted, that the portion of time occupied in the acquisition of any art will depend on the difficulty of its execution; and that the greater the number of distinct processes, the longer will be the time which the apprentice must employ in acquiring it.

There are many advantages to learning a few instead of all the different processes in a trade.

"2. Of waste of material in learning."\(^{19}\) -- If a person learns only a few arts, he will spoil much less material than if he tries to learn many arts. This will help to diminish the price of production.

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18 The material of this chapter was the first main topic of part two of the introductory essay.

19 This idea was expressed in the introductory essay but it was not presented as a sub-heading until the second edition.
3. Another advantage resulting from the division of labour is, the saving of that portion of time which is always lost in changing from one occupation to another. When the human hand, or the human head, has been for some time occupied in any kind of work, it cannot instantly change its employment with full effect. The muscles of the limbs employed have acquired a flexibility during their exertion, and those not in action a stiffness during rest, which renders every change slow and unequal in the commencement. Long habit also produces in the muscles exercised a capacity for enduring fatigue to a much greater degree than they could support under other circumstances. A similar result seems to take place in any change of mental exertion; the attention bestowed on the new subject not being so perfect at first as it becomes after some exercise.

4. Change of tools. — The employment of different tools in the successive processes is another cause of the loss of time in changing from one operation to another. If these tools are simple, and the change is not frequent, the loss of time is not considerable; but in many processes of the arts the tools are of great delicacy, requiring accurate adjustment every time they are used; and in many cases the time employed in adjusting bears a large proportion to that employed in using the tool.

Thus some manufactures find it "good economy to keep one machine constantly employed in one kind of work."

5. Skill acquired by frequent repetition of the same process. — The constant repetition of the same process necessarily produces in the workman a degree of excellence and rapidity in his particular department, which is never possessed by a person who is obliged to execute many different processes. This rapidity is still further increased from the circumstance that most of the operations in factories, where the division of labour is carried to a considerable extent, are paid for as piecework.

6. The division of labour suggests the contrivance of tools and machinery to execute its processes. — When each process, by which any article is produced, is the sole occupation of one individual his whole attention being devoted, to a very limited and simple operation, improvements in the form of his tools, or in the mode of using them, are much more likely to occur to his mind, than if it were distracted by a greater variety of circumstances. Such an improvement in the tool is generally the first

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20 Set aside as a separate sub-heading in the second edition.
step towards a machine. If a piece of metal is to be cut in a lathe, for example, there is one particular angle at which the cutting-tool must be held to insure the cleanest cut; and it is quite natural that the idea of fixing the tool at that angle should present itself to any intelligent workman.

When each process has been reduced to the use of some simple tool, the union of all these tools, actuated by one moving power, constitutes a machine...in order to make such combinations with any reasonable expectation of success, an extensive knowledge of machinery, and the power of making mechanical drawings are essentially requisite.

Such are the principles usually assigned as the causes of the advantage resulting from the division of labour. As in the view I have taken of the question, the most important and influential cause has been altogether unnoticed...it appears to me, that any explanation of the cheapness of manufactured articles, as consequent upon the division of labour, would be incomplete if the following principle were omitted to be stated.

That the master manufacturer, by dividing the work to be executed into different processes, each requiring different degrees of skill or of force, can purchase exactly that precise quantity of both which is necessary for each process; whereas, if the whole work were executed by one workman, that person must possess sufficient skill to perform the most difficult, and sufficient strength to execute the most laborious, of the operations into which the art is divided.21

"As the clear apprehension of this principle, upon which a great part of the economy arising from the division of labour depends, is of considerable importance, it may be desirable to point out its precise

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21 "The writer of this Essay [Babbage] derived his first knowledge of this principle from a personal examination of a variety of Manufactories and Workshops devoted to different purposes; but he has since found that it has been distinctly stated in the Work of Gioja, Nuovo Prospetto delle Scienze Economiche, 6 tom. 4 to. Milano, 1815, tom. I. capo iv." Ref. Babbage, Charles "Introductory View of the Principles of Manufactures." Encyclopaedia Metropolitana, London: B. Fellows, et al., VIII, p. 36, (footnote).
and numerical application in some specific manufacture." The example of pin-making is used for that is the one used by Adam Smith and we possess "A very accurate and minute description of that art, as practiced in France above half a century ago."22

A detailed discussion of pin-making is given, including the following tabulation of time and cost data for both English and French manufacturers.

**English Manufacture.**

"Pins, 'Elevens,' 5,546 weigh one pound; 'one dozen'—6,932 pins weigh twenty ounces, and require six ounces of paper. (See Table I)

**French Manufacture.**

Cost of 12,000 pins, No. 6, each being eight-tenths of an English inch in length,—as they were manufactured in France about 1760; with the cost of each operation: deduced from the observations and statement of M. Perronet. (See Table II)

An analysis of the cost and time data in the pin-making examples indicates that if the division of labour were not used pins would cost three and three-fourths times as much as they do with the division of labour. Recently an American has invented a machine to make pins. Its mode of operation and possible advantages and disadvantages are discussed.

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22 The following tabulation of French pin-making is sometimes referred to as the earliest example of timing of operations but the true source is not generally recognized. At least one of the sources is "Art De L'Epinglier," par M. deReaumur. Avec des Additions de M. Duhamel du Monceau, & des Remarques extraites des Memoires de M. Perronet, Inspecteur Général des Ponts & Chaussées., in the book Descriptions des Arts et Métiers, faites ou approuvées par Messieurs
<table>
<thead>
<tr>
<th>Name of the Process</th>
<th>Workman</th>
<th>Time for making 1 lb. of Pins</th>
<th>Cost of making 1 lb. of Pins</th>
<th>Workman earns per Day</th>
<th>Price of making each Part of a single Pin, in Millionths of a Penny</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Drawing Wire (§ 224,)</td>
<td>Man..</td>
<td>.3636</td>
<td>1.2500</td>
<td>3 3</td>
<td>225</td>
</tr>
<tr>
<td>2. Straightening wire (§ 225.)</td>
<td>Woman (§ 225.)</td>
<td>.3000</td>
<td>.2860</td>
<td>1 0</td>
<td>51</td>
</tr>
<tr>
<td>3. Pointing... (§ 226.)</td>
<td>Man..</td>
<td>.3000</td>
<td>1.7750</td>
<td>5 3</td>
<td>319</td>
</tr>
<tr>
<td>4. Twisting and Cutting Heads... (§ 227.)</td>
<td>Boy..</td>
<td>.0100</td>
<td>.0147</td>
<td>0 4.5</td>
<td>3</td>
</tr>
<tr>
<td>5. Heading.... (§ 228.)</td>
<td>Woman</td>
<td>.0000</td>
<td>5.0000</td>
<td>1 3</td>
<td>901</td>
</tr>
<tr>
<td>6. Tinning, or Whitening...... (§ 229.)</td>
<td>Man..</td>
<td>.1071</td>
<td>.6666</td>
<td>6 0</td>
<td>121</td>
</tr>
<tr>
<td>7. Papering... (§ 230.)</td>
<td>Woman</td>
<td>2.1314</td>
<td>3.1973</td>
<td>1 6</td>
<td>576</td>
</tr>
</tbody>
</table>

| Total | 7.6892 | 12.8732 | 2320 |

Number of Persons employed: Men, 4; Women, 4; Children, 2. Total 10.
<table>
<thead>
<tr>
<th>Name of the Process</th>
<th>Time for making Twelve Thousand Pins</th>
<th>Cost of making Twelve Thousand Pins</th>
<th>Workman usually earns per Day</th>
<th>Expense of Tools and Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Wire</td>
<td>Hours 22</td>
<td>Pence</td>
<td>Pence 24.75</td>
<td>Pence 24.75</td>
</tr>
<tr>
<td>2. Straightening and Cutting</td>
<td>Hours 1.2</td>
<td>Pence 0.5</td>
<td>Pence 4.5</td>
<td>Pence 11.0</td>
</tr>
<tr>
<td>(Coarse Pointing)</td>
<td>Hours 1.2</td>
<td>Pence 625</td>
<td>Pence 10.0</td>
<td>Pence 11.0</td>
</tr>
<tr>
<td>(Turning Wheel*)</td>
<td>Hours 1.2</td>
<td>Pence 675</td>
<td>Pence 7.0</td>
<td>Pence 11.0</td>
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<tr>
<td>3. Fine Pointing</td>
<td>Hours 1.2</td>
<td>Pence 625</td>
<td>Pence 9.375</td>
<td>Pence 11.0</td>
</tr>
<tr>
<td>(Turning Wheel)</td>
<td>Hours 1.2</td>
<td>Pence 675</td>
<td>Pence 9.375</td>
<td>Pence 11.0</td>
</tr>
<tr>
<td>(Cutting off pointed Ends)</td>
<td>Hours 0.6</td>
<td>Pence 375</td>
<td>Pence 7.5</td>
<td>Pence 11.0</td>
</tr>
<tr>
<td>(Turning Spiral)</td>
<td>Hours 0.5</td>
<td>Pence 125</td>
<td>Pence 3.0</td>
<td>Pence 11.0</td>
</tr>
<tr>
<td>4. Cutting off Heads</td>
<td>Hours 0.8</td>
<td>Pence 375</td>
<td>Pence 5.625</td>
<td>Pence 11.0</td>
</tr>
<tr>
<td>(Fuel to anneal ditto)</td>
<td>Hours 0.8</td>
<td>Pence 375</td>
<td>Pence 5.625</td>
<td>Pence 11.0</td>
</tr>
<tr>
<td>5. Heading</td>
<td>Hours 12.0</td>
<td>Pence 333</td>
<td>Pence 4.25</td>
<td>Pence 11.0</td>
</tr>
<tr>
<td>6. Tartar for Cleaning</td>
<td>Hours 0.5</td>
<td>Pence 125</td>
<td>Pence 3.0</td>
<td>Pence 5.0</td>
</tr>
<tr>
<td>(Tartar for Whitening)</td>
<td>Hours 0.5</td>
<td>Pence 125</td>
<td>Pence 3.0</td>
<td>Pence 5.0</td>
</tr>
<tr>
<td>7. Papering</td>
<td>Hours 4.8</td>
<td>Pence 5</td>
<td>Pence 2.0</td>
<td>Pence 5.0</td>
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<tr>
<td>Paper</td>
<td>Hours 0.5</td>
<td>Pence 125</td>
<td>Pence 3.0</td>
<td>Pence 5.0</td>
</tr>
<tr>
<td>Wear of Tools</td>
<td>Hours 0.5</td>
<td>Pence 125</td>
<td>Pence 3.0</td>
<td>Pence 5.0</td>
</tr>
</tbody>
</table>

\[24.3 \quad 4.708\]

*The great expense of turning the wheel appears to have arisen from the person so occupied being unemployed during half his time, whilst the pointer went to another manufactory.*
Chapter IX - The Division of Labour (pp. 191-202)

We have already mentioned what may, perhaps appear paradoxical to some of our readers — that the division of labour can be applied with equal success to mental as to mechanical operations, and that it insures in both the same economy of time. A short account of its practical application, in the most extensive series of calculations ever executed, will offer an interesting illustration of this fact, whilst at the same time it will afford an occasion for shewing that the arrangements which ought to regulate the interior economy of a manufactory, are founded on principles of deeper root than may have been supposed; and are capable of being usefully employed in preparing the road to some of the sublimest investigations of the human mind.

The most extensive series of calculations refers to the calculation by the French of various mathematical tables under the supervision of M. Prony. In this undertaking M. Prony combined the idea popularized by Adam Smith, the division of labor, and the mathematical method of differences to construct a table of logarithms. The method of producing this table was to divide the work among three groups of people. The first group consisted of the six most eminent mathematicians in France who determined what formulae were to be followed. The second group converted the formulae into numbers, and supervised and checked the work of the third group. The third group were the most numerous and completed the above calculations by means of simple addition and subtraction.

The operation of a factory is somewhat similar to these three groups. Someone having, by his own genius, or through the aid of his

dé L'Académic Royale des Sciences, Avec Figures en Taille-Douce.
Paris: chez Desaint & Saillant, Libraires, rue Saint Jean de Beauvais, M. DCC. LXI, avec Approbation & Privilege du Roi. (See Chapter VIII for further comment on M. Perronet.)

23 This was part of the topic "Division of Labour" in the introductory essay.
friends, found that some improved machinery can be successfully applied to his pursuit, makes drawings and plans for the operation, and may be considered as constituting the first group. The second group are the operating engineers and superintendents. The third group are the multitude of other persons who must be employed to carry out the work.

As the possibility of performing arithmetical calculations by machinery...is connected with the subject of the division of labour, I shall here endeavour, in a few lines, to give some slight perception of the manner in which this can be done, and thus remove a small portion of the veil which covers that mystery.

That nearly all tables of numbers which follow any law, however complicated, may be formed, to a greater or less extent, solely by the proper arrangement of the successive addition and subtraction of numbers befitting each table, is a general principle which can be demonstrated...

This is explained with several examples.

We have seen, then, that the effect of the division of labour both in mechanical and in mental operations is, that it enables us to purchase and apply to each process precisely that quantity of skill and knowledge which is required for it...

The division of labour cannot be successfully practiced unless there exists a great demand for its produce; and it requires a large capital to be employed in those arts in which it is used.

In one of the most difficult arts, that of Mining, great improvements have resulted from the judicious distribution of the duties; and under the arrangements which have gradually been introduced, the whole system of the mine and its government is now placed under the control of the following officers. 2h

1. A Manager, who has the general knowledge of all that is to be done, and who may be assisted by one or more skilful persons.

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2h This example added in the second edition.
2. Underground Captains direct the proper mining operations, and govern the working miners.

3. The Purser and Book-keeper manage the accounts.

4. The Engineer erects the engines, and superintends the men who work them.

5. A chief Pitman has charge of the pumps and the apparatus of the shafts.

6. A Surface-captain, with assistants, receives the ores raised, and directs the dressing department, the object of which is to render them marketable.

7. The head Carpenter superintends many constructions.

8. The foreman of the Smiths regulates the iron work and tools.


10. The Roper has charge of ropes and cordage of all sorts.

Chapter XXI - The Cost of Each Separate Process in a Manufacture
(pp. 203-210)

The great competition introduced by machinery, and the application of the principle of the subdivision of labour, render it necessary for each producer to be continually on the watch, to discover improved methods by which the cost of the article he manufactures may be reduced; and, with this view, it is of great importance to know the precise expense of every process, as well as the wear and tear of machinery which is due to it. The same information is desirable for those by whom the manufactured goods are distributed and sold; because it enables them to give reasonable answers or explanations to the objections of inquirers, and also affords them a better chance of suggesting to the manufacturer changes in the fashion of his goods, which may be suitable either to the tastes or to the finances of his customers. To the statesman such knowledge is

25 This material was introduced in the first edition.
still more important; for without it he must trust entirely to others, and can form no judgment worthy of confidence, of the effect any tax may produce, or of the injury the manufacturer or the country may suffer by its imposition.

A knowledge of costs also indicates the places where there are the most potential savings to be made.

As an example of the costs of different processes of manufacture, the costs of publishing this book are tabulated and explained.

Chapter XXII - The Causes and Consequences of Large Factories (pp. 211-224)26

"On examining the analysis which has been given in Chapter XIX of the operations in the art of pin-making, it will be observed, that ten individuals are employed in it, and also that the time occupied in executing the several processes is very different." Now let us suppose, in order to simplify the reasoning, that each process requires an equal quantity of time. "This being supposed, it is at once apparent, that, to conduct an establishment for pin-making most profitably, the number of persons employed must be a multiple of ten...The same reflection constantly presents itself on examining any well-arranged factory." The factory of Mr. Mordan, the patentee of the ever-pointed pencils gives us an example of balanced operations. If it were necessary to enlarge this factory, it is clear that it should be done in even multiples of this basic number of workmen.

26 In the introductory essay this was called "On the Size of Factories."
Thus,

...we arrive at this general conclusion: -- When the number of processes into which it is most advantageous to divide it, and the number of individuals to be employed in it, are ascertained, then all factories which do not employ a direct multiple of this latter number, will produce the article at a greater cost. This principle ought always to be kept in view in great establishments, although it is quite impossible, even with the best division of the labour, to attend to it rigidly in practice. The proportionate number of the persons who possess the greatest skill, is of course to be first attended to. That exact ratio which is most profitable for the factory employing a hundred workmen, may not be quite the best where there are five hundred, and the arrangements of both may probably admit to variations, without materially increasing the cost of their produce. But it is quite certain that no individual, nor in the case of pin-making could any five individuals ever hope to compete with an extensive establishment. Hence arises one cause of the great size of manufacturing establishments, which have increased with the progress of civilization. Other circumstances, however, contribute to the same end, and arise also from the same cause—the division of labour.

The material out of which the manufactured article is produced, must, in the several stages of its progress, be conveyed from one operator to the next in succession: this can be done at least expense when they are all working in the same establishment.

The inducement to contrive machines for any process of manufacture increases with demand for the article; and the introduction of machinery, on the other hand, tends to increase the quantity produced, and to lead to the establishment of large factories. An illustration of these principles may be found in the history of the manufacture of patent net.

As the application of steam power replaces the physical force of man, one worker can often attend to more than one machine. As the factories increase in size it is necessary to employ men to do the following: repair the machinery, handle the factory lighting, be

27 The above modifications to the underlined statement were added in the first edition.
accountants and pay clerks, and agents to purchase the raw produce and sell the manufactured article. 28

We have seen that the application of the Division of Labour tends to produce cheaper articles; that it thus increases the demand; and gradually, by the effect of competition, or by the hope of increased gain, that it causes large capitals to be embarked in extensive factories. Let us now examine the influence of this accumulation of capital directed to one object. In the first place, it enables the most important principle on which the advantage of the division of labour depends to be carried almost to its extreme limits: not merely in the precise amount of skill purchased which is necessary for the execution of each process, but throughout every stage, — from that in which the raw material is produced, to that by which the finished produce is conveyed into the hands of the consumer, the same economy of skill prevails. The quantity of work produced by a given number of people is greatly augmented by such an extended arrangement; and the result is necessarily a great reduction in the cost of the article which is brought to market. 29

With large factories more care can be taken to prevent waste of any part of the raw material. "An attention to this circumstance sometimes causes the union of two trades in one factory, which otherwise might have been separated." The use of cattle horns is an example of this.

Another event which has arisen, in one trade at least, from the employment of large capital, is, that a class of middle-men, formerly interposed between the maker and the merchant, now no longer exists. 29

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28 Topic of profit sharing followed this point in the introductory essay and in the first edition.

29 The above paragraph and ideas of the following four paragraphs were included in "Of the Effects of Great Capitals Employed in Manufactures" in the introductory essay.
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The value of character, though great in all circumstances of life, can never be so fully experienced by persons possessed of small capital as by those employing much larger sums: whilst these large sums of money for which the merchant deals, render his character for punctuality more studied and known by others.

The amount of well-grounded confidence, which exists in the character of its merchants and manufactures, is one of the many advantages that an old manufacturing country always possesses over its rivals.

The larger establishments can afford to employ specialists to take advantages of provisions provided by the law, to seek special sources of raw material, and to conduct experiments which would be ruinous to smaller establishments. Testimony before the House of Commons on the Woolen Trade, in 1806, substantiates this.30

Chapter XXIII - The Position of Large Factories (pp. 225-230)

It is found in every country, that the situation of large manufacturing establishments is confined to particular districts. In the early history of a manufacturing community, before cheap modes of transportation have been extensively introduced, it will almost always be found that manufactories are placed near those spots in which nature has produced the raw material; especially in the case of articles of great weight, in those the value of which depends more upon the material than upon the labor expended on it.

The availability of fuel and power are also considerations.

Rivers form the earliest means of good transportation. "Canals will succeed, or lend their aid to these; and the yet unexhausted applications of steam and of gas, hold out a hope of attaining almost the same advantages for countries to which nature seems forever to

30 Contents of the above paragraph were added in the first edition.
have denied them. Manufacturers, commerce, and civilization, always follow the line of new and cheap communications." The territory served by the Mississippi River is an example of country that has been opened up by steam in the last twenty years.

The accumulation of many large manufacturing establishments in the same district has a tendency to bring together purchasers or their agents from great distances, and thus to cause the institution of a public mart or exchange. The very circumstance of collecting periodically, at one place, a large number of both those who supply the market and those who require its produce, tends strongly to check the accidental fluctuations to which a small market is always subject, as well as to render the average of the prices much more uniform.

When capital has been invested in machinery and in buildings for its accommodation, and when the inhabitants of a neighborhood have acquired a knowledge of the modes of working at their machines, reasons of considerable weight are required to cause its removal. Such changes of position do however occur; and they have been alluded to by the Committee on the Fluctuation of Manufacturers' Employment, as one of the causes interfering most materially with an uniform rate of wages; it is therefore of particular importance to the workmen to be acquainted with the real causes which have driven manufacturers from their ancient seats.

Any violence used by the workmen against the property of their masters, and any unreasonable combination on their part, is almost sure thus to be injurious to themselves.

Another circumstance which influences the removal of factories is the nature of its machinery for it is difficult to move a factory which uses heavy machinery driven by a central source of power.

It is of great importance that the more intelligent amongst the class of workmen should examine into the correctness of these views; because, without having their attention directed to them, the whole class may, in some instances, be led by designing
persons to pursue a course, which, although plausible in appearance, is in reality at variance with their own best interests.

Chapter XXIV - Over-Manufacturing (pp. 231-241)³²

One of the natural and almost inevitable consequences of competition is the production of a supply much larger than the demand requires. This result usually arises periodically; and it is equally important, both to the masters and to the workmen, to prevent its occurrence, or to foresee its arrival. In situations where a great number of very small capitalists exists, -- where each master works himself and is assisted by his own family, or by a few journeymen, -- and where a variety of different articles is produced,

the practices carried out by certain middle-men or factors sometimes help to reduce the fluctuations which occur in price.

Where there is over-manufacturing by a few large establishments the effect is different. When an over supply has reduced prices, the wages of labor can be reduced or the hours of laborers can be cut, until supply again adjusts itself to demand and prices regain their former level. The latter case is probably the best, for both the masters and the workmen, but difficult to carry out unless there is a combination amongst the masters or amongst the workmen, and this has its evils.

It would be highly interesting, if we could trace, even approximately, through the history of any great manufacturer, the effects of gluts in producing improvements in machinery, or in the methods of working; and if we could shew that addition to the annual quantity of goods previously manufactured, was produced by each alteration. It would probably be found, that the increased quantity manufactured by the same capital, when worked with the new improvement, would produce nearly the same rate of profit as other modes of investment.

³² Material added in first edition.
Perhaps the manufacture of iron would be a good one to study.

Various aspects and experiments for study are suggested.

Superior industry and attention will enable some factories to make a profit rather beyond the rest; superior capital in others will enable them, without these advantages, to support competition longer, even at a loss, with the hope of driving the smaller capitalists out of the market and then reimbursing themselves by an advanced price. It is, however, better for all parties, that this contest should not last long; and it is important, that no artificial restraint should interfere to prevent it.

It is not pretended, in this short view, to trace out all the effects or remedies of over-manufacturing; the subject is difficult, and, unlike some of the questions already treated, requires a combined view of the relative influence of many concurring causes.

Chapter XXV - Inquiries Previous to Commencing Any Manufactory

( pp. 242-249)³³

There are many inquiries which ought always to be made previous to the commencement of the manufacture of any new article. These chiefly relate to the expense of tools, machinery, raw materials, and all the outgoings necessary for its production, -- to the extent of demand which is likely to arise, -- to the time in which the circulating capital will be replaced, -- and to the quickness or slowness with which the new article will supersede those already in use.

The expense of tools and of new machines will be more difficult to ascertain, in proportion as they differ from those already employed; but the variety and constant use in our various manufactories, is such, that few inventions now occur in which considerable resemblance may not be traced to others already constructed. The cost of the raw material is usually less difficult to determine; but cases occasionally arise in which it becomes important to examine whether the supply, at the given price, can be depended upon: for, in the case of a small consumption, the additional demand arising from a factory may

³³ Material added in first edition.
produce a considerable temporary rise though it may ultimately reduce the price.

The quantity of any new article likely to be consumed is a most important subject for the consideration of the projector of a new manufacture.

In many instances it is exceedingly difficult to estimate beforehand the sale of an article, or the effects of a machine:...

Reports of committees of the House of Commons testify to these facts.

In establishing a new manufactory, the time in which the goods produced can be brought to market and the returns be realized, should be thoroughly considered, as well as the time the new article will take to supersede those already in use. If it is destroyed in using, the new produce will be much more easily introduced.

Another element in this question which should not be altogether omitted, is the opposition which the new manufacturer may create by its real or apparent injury to other interests, and the probable effect of that opposition. This is not always foreseen; and when anticipated is often inaccurately estimated.

The examples of the establishment of certain steamboat lines show this.

Chapter XXVI - A New System of Manufacturing (pp. 250-259)

A most erroneous and unfortunate opinion prevails amongst workmen in many manufacturing countries, that their own interests and that of their employers are at variance. The consequences are, -- that valuable machinery is sometimes neglected, and even privately injured, -- that new improvements, introduced by the masters, do not receive a fair trial, -- and that the talents in observations of the workmen are not directed to the improvement of the processes in which they are employed...

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34 Part of these contents appeared under the topics "On the Size of Factories" in the introductory essay, and in the chapter, "On the Causes and Consequences of Large Factories," in the first edition.
Convinced as I am, from my own observations, that the prosperity and success of the master manufacturer is essential to the welfare of the workman, I am yet compelled to admit that this connexion is, in many cases, too remote to be always understood by the latter: and whilst it is perfectly true that workmen, as a class, derive advantage from the prosperity of their employers, I do not think that each individual partakes of that advantage exactly in proportion to the extent to which he contributes toward it; nor do I perceive that the resulting advantage is as immediate as it might become under a different system.\textsuperscript{35}

It would be of great importance, if, in every large establishment the mode of payment could be so arranged, that every person employed should derive advantage from success of the whole; and that the profits of each individual should advance, as the factory itself produced profit, without the necessity of making any changes in wages. This is by no means easy to effect, particularly amongst that class whose daily labour procures for them their daily food.

The system used at the Cornish mines, although not exactly fulfilling these conditions, meets some of the requirements and its method of operation is explained.\textsuperscript{36}

I shall now present the outline of a system which appears to me to be pregnant with the most important results, both to the class of workmen and to the country at large; and which, if acted upon, would, in my opinion, permanently raise the working classes, and greatly extend the manufacturing system.\textsuperscript{37}

The general principles on which the proposed system is founded, are —

1st. That a considerable part of the wages received by each person employed should depend on the profits made by the establishment; and,

\textsuperscript{35} New paragraph in second edition.

\textsuperscript{36} From the introductory essay.

\textsuperscript{37} This paragraph and the rest of the chapter, except for the example of the Cornish mines, was added in the second edition.
2d. That every person connected with it should derive more advantage from applying any improvement he might discover, to the factory which he is employed, than he could by any other course.

It would be difficult to prevail on the large capitalist to enter upon any system, which would change the division of the profits arising from the employment of his capital in setting skill in labour in any action; any alteration, therefore, must be expected rather from the small capitalist, or from the higher class of workmen, who combine the two characters; and to these latter classes, whose welfare will be first affected, the change is most important. I shall therefore first point out the course to be pursued in making the experiments; and then, taking a particular branch of trade as an illustration, I shall examine the merit and defects of the proposed system as applied to it.

A theoretical example for sharing the profits is set forth and

...the first question to be settled is, what proportion of the profits should be allowed for the use of capital, and what for skill and labour? It does not seem possible to decide this question by any abstract reasoning; if the capital supplied by each partner is equal, all difficulty will be removed; if otherwise, the proportion must be left to find its level, and will be discovered by experience; and it is probable that it will not fluctuate much. Accurate accounts should be kept of every expense and of all the sales; and at the end of each week the profits should be divided. A certain portion should be laid aside as a reserve fund, another portion for the repair of the tools, and the remainder being divided... amongst the capitalist and the workmen. "It is important that every person employed in the establishment, whatever might be the amount paid for his services...should receive one half of what his service is worth in fixed salary, the other part varying with the success of the undertaking."

It would be essential that the time occupied in each process, and also its expense, should be well ascertained; information which would soon be obtained varied precisely. Now, if a workman should find a mode of shortening any of
the processes, he would confer a benefit on the whole party, even if they received but a small part of the resulting profit. For the promotion of such discoveries, it would be desirable that those that make them should either receive some reward, to be determined after a sufficient trial by a committee assembling periodically; or if they be of high importance, that the discoverer should receive one-half, or two-thirds, of the profit resulting from them during the next year, or some other determinate period, as might be found expedient.

The result of such arrangements in a factory would be,

1. That every person engaged in it would have a direct interest in its prosperity; since the effect of any success, or falling off, would almost immediately produce a corresponding change in his own weekly receipts.

2. Every person concerned in the factory would have an immediate interest in preventing any waste or mismanagement in all the departments.

3. The talents of all connected with it would be strongly directed to its improvement in every department.

4. None but workmen of high character and qualifications could obtain admission into such establishments; because when any additional hands were required, it would be the common interest of all to admit only the most respectable and skillful; and it would be far less easy to impose upon a dozen workmen than upon the single proprietor of a factory.

5. When any circumstance produced a glut in the market, more skill would be directed to diminishing the cost of production; and a portion of the time of the men might then be occupied in repairing and improving their tools, for which a reserved fund would pay, thus checking present, and at the same time facilitating future production.

6. Another advantage, of no small importance, would be the total removal of all real or imaginary causes for combinations. The workman and the capitalist would so shade into each other,—would so evidently have a common interest, and their difficulties and distresses would be mutually so well understood, that, instead of combining to oppress one another, the only combination which could exist would be a most powerful union between both parties to overcome their common difficulties.
One of the difficulties attending such a system is, that capitalists would at first fear to embark in it, imagining that the workmen would receive too large a share of the profits; and it is quite true that the workmen would have a larger share than at present; but, at the same time, it is presumed the effect of the whole system would be, that the total profits of the establishment bring much increased, the smaller proportion allowed to capital under this system would yet be greater in actual amount, than that which results to it from the larger share in the system now existing.

A difficulty would occur also in discharging workmen who behaved ill, or who were not competent to their work; this would arise from their having a certain interest in the reserve fund, and, perhaps, from their possessing a certain portion of the capital employed; but without entering into detail, it may be observed, that such cases might be determined on by meetings of the whole establishment; and that if the policy of the laws favoured such establishments, it would scarcely be more difficult to enforce just regulations, than it now is to enforce some which are unjust, by means of combinations either amongst the masters or the men.

Systems similar to this are now used in the Cornish mines and on whaling ships.

Chapter XXVII - Contriving Machinery (pp. 260-267)38

The power of inventing mechanical contrivances, and of combining machinery, does not appear, if we may judge from the frequency of its occurrence, to be a difficult or rare gift.

It is however a curious circumstance, that although the power of combining machinery is so common, yet the more beautiful combinations are exceedingly rare.

...it is possible to construct the whole machine upon paper and to judge if the proper strength to be given to each part as well as to the frame-work which supports it, and also of its

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38 This was part of the topic "Of the Proper Circumstances for the Application of Machinery" in the introductory essay.
ultimate effect, long before a single part of it has been ex-
ecuted. In fact, all the contrivance, and all the improvements,
ought first to be represented in the drawings.

On the other hand, there are effects dependent upon physi-
cal or chemical properties for the determination of which no
drawings will be of any use. These are the legitimate objects
of direct trial.

The next stage in the progress of an invention, after the
derawings are finished and the preliminary experiments have been
made, if any such should be requisite, is the execution of the
machine itself. It can never be too strongly impressed upon
the minds of those who are devising new machines, that to make
the most perfect drawings of every part tends essentially both
to the success of the trial, and to the economy in arriving at
the result.

Errors "frequently arise from having neglected to take into con-
sideration that metals are not perfectly rigid but elastic."

"Again, a strength in stiffness of framing which supports the
mechanism must be carefully attended to." This includes the structure
of the building itself and the support of long drive shafts.

If the experiment is worth making, it ought to be tried with
all the advantages of which the state of mechanical arts admits;
for an imperfect trial may cause an idea to be given up, which
better workmanship might have proved to be practicable.

It is partly owing to the imperfection of the original
trials, and partly to the gradual improvements in the art of
making machinery, that many inventions which have been tried,
and given up in one state of art, have at another period been
eminently successful.

When the drawings of a machine have been properly made,
and the parts been well executed, and even when the work
it produces possesses all the qualities which were anticipated,
still the invention may fail; that is, it may fail of being
brought into general practice. This will most frequently arise
from the circumstance of its producing its work at a greater
expense than that at which it can be made at other methods.
Whenever the new, or improved machine, is intended to become the basis of a manufacture, it is essentially requisite that the whole expense attending its operations should be fully considered before its construction is undertaken. It is almost always very difficult to make this estimate of the expense: the more complicated the mechanism, the less easy is the task;...

The first machine produced will always cost more than later copies.

...it is a maxim equally just in all the arts, and in every science, that the man who aspires to fortune or to fame by new discoveries, must be content to examine with care the knowledge of his contemporaries, or to exhaust his efforts in inventing again what he will most probably find has been better executed before.

Chapter XXVIII - Proper Circumstances for the Application of Machinery

The first object of machinery, the chief cause of its extensive utility, is the perfection and the cheap production of the articles which it is intended to make. Whenever it is required to produce a great multitude of things, all of exactly the same kind, the proper time has arrived for the construction of tools or machines by which they may be manufactured.

Whenever it is required to produce a few articles, -- parts of machinery, for instance, which must be executed with the most rigid accuracy or be perfectly alike, -- it is nearly impossible to fulfil this condition, even with the aid of the most skilful hands; and it becomes necessary to make tools expressly for the purpose, although those tools should, as frequently happens, cost more in constructing than the things they are destined to make.

Another instance of the just application of machinery, even at an increased expense, arises where the shortness of time in which the article is produced, has an important influence on its value.

An example of this is the printing of newspapers.

The conveyance of letters is another case, in which the importance of saving time would allow of great expense in any new machinery
for its accomplishment." One means of speeding up the sending of letters might be to send them along tightly strong wires which run between cities. "Nor is it impossible that stretched wire might itself be available for a species of telegraphic communication yet more rapid."

Perhaps if the steeple of churches, properly selected, were made use of, connecting them by a few intermediate stations some great central building, as, for instance, the top of St. Paul's; and if a similar apparatus were placed on top of each steeple, with a man to work it during the day, it might be possible to diminish the expense of the two-penny post, and make deliveries every half hour over the great part of the metropolis. 39

The power of steam, however, bids fair almost to rival the velocity of these contrivances;...

for the steam-carriages have great potential.

39 This paragraph suggesting the use of church steeples as stations along which the two-penny post might be sent was added in the first edition. It invoked comments such as the following: "Mr. Babbage, in his admirable little work on the Economy of Manufacturers, has a new plan of conveying the mail...deliveries would, of course, take place every quarter of an hour, and the next improvement would be that the two-penny postman should come in at the window instead of the door, like the dove letter carrier of the Alhambra. The correspondence of both town and country would at least be carried on openly, and a very pretty spectacle it would be to see the cylinders sliding through the air in all directions and to hear the whir of the post a hundred yards overhead, like a bird in full flight. We may suggest that there would be no fear of the post or pillarmen (these new Simons Stylites of the philosopher) sleeping at their stations; for the Comptroller-general might, by means of the wireless, communicate an electric shock every now and then by way of avvent courier to the mail, or to enlighten attention in case of any extraordinary dispatch. In this manner, also, a reprimand might be conveyed in an instant, and, while the Postmaster-general was sitting at his ease in the dome of Saint Paul's, he might give a Welsh or a Scotch postmaster such a rap over the knuckles as he would not be likely soon to forget...." Ref. "A Novelty in Posting." The New Monthly Magazine and Literary Journal, 1832, Part II, Volume 35, page 92.
The time during which a machine will continue to perform its work effectively, will depend chiefly upon the perfection with which it was originally constructed, — upon the care taken to keep it in proper repair, particularly to correct every shake or looseness in the axis, — and upon the smallness of the mass and the velocity of its moving parts. Everything approaching to a blow, all sudden change of direction, is injurious.

Machinery for producing any commodity in great demand, seldom actually wears out; new improvements, by which the same operations can be executed either more quickly or better, generally superseding it long before that period arrives: indeed, to make such an improved machine profitable, it is usually reckoned that in five years it ought to have paid for itself, and in ten to be superseded by a better.

Machines are, in some trades, let out to hire, and a certain sum is paid for their use, in the manner of rent.

House of Commons reports give various examples of this.\footnote{The above paragraph and remainder of chapter were added in the first edition.}

The evil of not assigning fairly to each tool, or each article produced, its proportionate value, or even of not having a perfectly distinct, simple, and definite agreement between a master and his workmen is very considerable. Workmen find it difficult in such cases to know the probable produce of their labour; and both parties are often led to adopt arrangements, which, had they been well examined, would have been rejected as equally at variance in the results with the true interests of both.

If any mode could be discovered of transmitting power, without much loss from friction, to considerable distances, and at the same time of registering the quantity made use of at any particular point, a considerable change would probably take place in many departments of the present system of manufacturing.

The most portable form in which power can be condensed is, perhaps, by the liquification of the gasses.
The effect of competition in cheapening articles of manufacture sometimes operates in rendering them less durable. When such articles are conveyed to a distance for consumption, if they are broken, it often happens, from the price of labour being higher where they are used than where they were made, that it is more expensive to mend the old article, than to purchase a new. Such is usually the case in great cities, with some of the commoner locks, with hinges, and with a variety of articles of hardware.

Chapter XXX - Combinations Amongst Masters or Workmen Against Each Other (pp. 293-311)

There exists amongst the workmen of almost all classes, certain rules or laws which govern their actions toward each other, and towards their employers. But, besides these general principles, there are frequently others peculiar to each factory, which have derived their origin, in many instances, from the mutual convenience of the parties engaged in them.

These rules should be examined.

"The principles by which such laws should be tried are,

"1st. That they conduce to the general benefit of all the persons employed.

"2dly. That they prevent fraud.

"3dly. That they interfere as little as possible with the free agency of each individual."

In many workshops a new journeyman pays a small fine to the rest of the men. This should be put to good use, and not to drink.

"In many workshops, the workmen, although employed on totally different parts of the objects manufactured, are yet dependent, in

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41 The phrase "against each other" was added in the first edition to distinguish it from the next added chapter "On Combinations of Masters Against the Public."
some measure, upon each other." Sometimes one worker's idleness or
intemperance holds up other workers.

It is reasonable, in such circumstances, that a fine
should be levied on the delinquent; but it is desirable that
the master should have concurred with his workmen in establish-
ing such a rule, and that it should be shown to each individual
previously to his engagement; and it is very desirable that
such fine should not be spent in drinking.

Bonuses for remarkable degrees of skill are worth-while if properly
used. Likewise, under piece-work, fines should be considered for work
badly executed.

Societies or associations among the workmen or among the masters
can serve a useful or an evil purpose.

Associations of workmen and of masters may, with advantage,
agree upon rules to be observed by both parties, in estimating
the proportionate value of different kinds of work executed in
their trade, in order that time may be saved, and disputes be
prevented. They may also be most usefully employed in acquir-
ing accurate information as to the number of persons working in
the various departments of any manufacture, their rate of wages,
the number of machines in use, and other statistical details.

One of the most legitimate and most important objects of
such associations as we have just mentioned is to agree upon
ready and certain modes of measuring the quantity of work done
by the workmen.

If the machines employed could register the quantity of work which they
perform it would sometimes eliminate serious grievances. 42

The effects arising from combinations amongst the workmen,
are almost always injurious to the parties themselves... As the
injury to the men and to their families is almost always more
serious than that which affects their employers, it is of the

42 Paragraph added in first edition.
utmost importance to the comfort and happiness of the former class, that they should themselves entertain sound views upon this question.

A few examples illustrate this principle.

The fact that some combinations are permanently injurious to the workmen does "not prove that all such combinations have this effect. It is quite evident that they all have this tendency..." If workers combine for only a small advance of wage, in all probability they will be much more successful than if they combine for too high a wage.

Due to threats of strikes it becomes necessary to keep on hand a larger stock of materials than would be required if it were certain that no combinations would arise. This in turn increases the price of the manufactured article and ties up capital.

If a strike exists and

...any of the trade refuse to join in the strike, the majority too frequently forget, in the excitement of their feelings, the dictates of justice, and endeavor to exert a species of tyranny, which can never be permitted to exist in a free country. In conceding therefore to the working classes, that they have a right, if they consider it expedient, to combine for the purpose of procuring higher wages (provided always, that they have completed all of their existing contracts), it ought ever to be kept before their attention that the same freedom which they claim for themselves they are found to allow to others, who may have different views of the advantages of combination. Every effort which reason and kindness can dictate, should be made, not merely to remove their grievances, but to satisfy their own reason and feelings, and to show them the consequences which will probably result from their conduct; but the strong arm of the law, backed, as in such cases it will always be, by public opinion, should be instantly and unhesitatingly applied, to prevent them from violating the liberty of a portion of their own, or of any other classes of society.43

43 The above paragraph and remainder of chapter added in the first edition.
Amongst the evils which ultimately fall heavy on the working class themselves, when, through mistaken views, they attempt to interfere with their employers in the mode of carrying on their business, may be mentioned the removal of factories to other situations, where the proprietors may be free from the improper control of their men.

One of the remedies employed by the masters against the occurrence of combinations, is to make engagements with their men for long periods, and to arrange them in such a manner, that these contracts shall not all terminate together... It is attended with the inconvenience to the masters that, during periods when the demand for their product is reduced, they are still obliged to employ the same number of workmen.

Sometimes workers unite to purchase and resell the most necessary items of food. The master may help by providing facilities, but he should not be interested in the profits made from articles sold. The workers ought not in the slightest degree, be compelled to make their purchases here.

Whenever the workmen are paid in goods, or are compelled to purchase at the master's shop, much injustice is done to them, and great misery results from it... Workmen should be paid entirely in money; -- their work should be measured by some unbiased, some unerring piece of mechanism; -- the time during which they are employed should be defined, and punctually adhered to. The payments they make to their benefit societies should be fixed on such just principles, as not to require extraordinary contributions. In short, the object of all who wish to promote their happiness should be, to give them, in the form, the means of knowing beforehand, the sum they are likely to acquire by their labor, and the money they will be obliged to spend for their support: thus putting before them, in the clearest light, the certain result of preserving industry.

Chapter XXXI - Combinations of Masters Against the Public (pp. 312-333)

\[\text{The first part of this chapter appeared under the topic "On Combinations amongst Masters or Workmen," in the introductory essay.}\]
"A species of combination occasionally takes place amongst manu-
ufacturers against persons having patents: and these combinations are
always injurious to the public, as well as unjust to the inventors."
Such combinations have refused to allow new improvements or new in-
ventions to be put into use.

There occurs another kind of combination against the
public, with which it is difficult to deal. It usually ends
in a monopoly, and the public are then left to the discretion
of the monopolist not to charge them above the 'growling
point;' -- that is, not to make them pay so much as to induce
them actually to combine against the imposition.
This occurs in public utilities where the capital required is very
large, and the competition very limited.

Perhaps one remedy against evils of this kind might be,
when a charter is granted to such companies, to restrict, to
a certain amount, the rate of profit on the shares, and to
direct that any profits beyond, shall accumulate for the re-
payment of the original capital...It must, however, be admitted,
that this would be an interference with capital, which, if
allowed, should, in the present state of our knowledge, be
examined with great circumspection in each individual case,
until some general principle is established on well-admitted
grounds.

An example of a combination against the public is that of the
book sellers, for they receive too high a proportion of what the
public pays for a book. As proof of this, examine the costs of dis-
tribution involved in this book.\footnote{The material of this paragraph was new in the first edition.}
Chapter XXII - The Effect of Machinery in Reducing the Demand for Labor (pp. 334-341)\[46]

"One of the objections most frequently urged against machinery is, that it has a tendency to supersede much of the hand-labour which was previously employed" although "the use of machinery has at first a tendency to throw labour out of employment, yet the increased demand consequent upon the reduced price, almost immediately absorbs a considerable portion of that labour, and perhaps, in some cases, the whole of what would otherwise have been displaced."

Various ramifications of this subject and examples are given in this chapter.

Chapter XXXIII - The Effect of Taxes and Legal Restrictions on Manufactures (pp. 342-363)

"As soon as a tax is put upon any article, the ingenuity of those who made, and those who use it, is directed to the means of evading as large a part of the tax as they can; and this may often be accomplished in ways which are perfectly fair and legal." The tax levied on windows and the changes it caused in housing architecture is an example of this. "A tax on windows is exposed to objection on the double ground of its excluding air and light, and is on both accounts injurious to health."

\[46] This was a new chapter heading in the second edition. It was, however, an amplification and illustration of material which appeared in the chapter, "Proper Circumstances for the Application of Machinery" in the first edition. The material was not in the introductory essay.
"It is frequently necessary for the purpose of revenue, to oblige manufacturers to take out a license, and to compel them to work according to certain rules, and to make certain stated quantities at each operation." This sometimes leads to stifling of experimentation and hindrance of progress.\(^7\)

The policy of giving Bounties upon home productions, and of enforcing restrictions against those which can be produced more cheaply in other countries, is of a very questionable nature: and, except for the purpose of introducing a new manufacturer, in a country where there is not much commercial or manufacturing spirit, is scarcely to be defended. All incidental modes of taxing one class of the community, the consumers, to an unknown extent, for the sake of supporting another class, the manufacturers, who would otherwise abandon that mode of employing their capital, are highly objectionable...If the sum of what the consumers are thus forced to pay, merely on account of the artificial restrictions, were generally known, its amount would astonish even those who advocate them; and it would be evident to both parties, that the employment of capital in those branches of trade ought to be abandoned.

The restriction of articles produced in a manufactory to certain sizes, is attended with some good effect in an economical view, arising chiefly from the smaller number of different tools required in making them, as well as from less frequent change in the adjustment of these tools.

The Navy makes good use of this standardization of parts and supplies.

"The effects of the removal of a monopoly are often very important..." The example of the many changes thus caused in the bobbin-net trade is discussed at length.

In order to encourage the invention, the improvement, or the importation of machines, and of discoveries relating to manufactures, it has been the practice in many countries, to grant to the inventors or first introducers, an exclusive

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\(^7\) The subject of this and the next paragraph were added in the first edition.
privilege for a term of years. Such monopolies are termed Patents; and they are granted, on the payment of certain fees, for different periods, from five to twenty years.

It is clearly of importance to preserve to each inventor the sole use of his invention, until he shall have been amply repaid for the risk and expense to which he has been exposed, as well as for the talent he has exerted in completing it. But, the degrees of merit are so various, and the difficulties of legislating upon the subject so great, that it has been found almost impossible to frame a law which shall not, practically, be open to the most serious objections.

The question of permitting by law, the existence of partnerships in which the responsibility of one or more of the partners is limited in amount, is peculiarly important in a manufacturing, as well as a commercial point of view. In the former light, it appears calculated to aid that division of labour, which we have already proved to be as advantageous in mental as it is in bodily operations; and it might possibly give rise to a more advantageous distribution of talent, and its combinations, that at present exists.

This law seems to promise advantage to the extension of manufacturers, though it is by no means free from grave objections.

The principle, that Government ought to interfere as little as possible between workmen and their employers, is so well established, that it is important to guard against its misapplication. It is not inconsistent with this principle to insist on the workmen being paid in money, -- for this is merely to protect them from being deceived.

Limits should be placed on the hours of work for children, and their age of employment, for they are not free agents.

Chapter XXIV - The Exportation of Machinery (pp. 364-378)

It is contended that by admitting the exportation of

48 The above paragraph was added in the first edition.

49 The above paragraph was added in the second edition.
machinery, foreign manufacturers will be supplied with machines equal to our own. The first answer which presents itself to this argument is supplied by almost the whole of the present volume: That in order to succeed in a manufacture, it is necessary not merely to possess good machinery, but that the domestic economy of the factory should be most carefully regulated.

If the exportation of machinery is allowed, we will increase the more intelligent class of our workmen, the machine builders.

"Another argument in favor of the exportation of machinery, is, that it would facilitate the transfer of capital to any more advantageous mode of employment which might present itself." This is due to the fact that in some ventures, once the capital is committed, very little can be recovered by scrapping the business whereas if the machinery could be sent abroad more capital could be recovered and turned to other uses.

When considering competition from abroad, attention should be paid to their means of transport. As compared to that of England, most foreign countries are not nearly as well equipped with means of transport.

Chapter XXXV - The Future Prospects of Manufactures, as Connected With Science (pp. 379-392)

The arts and manufactures of the country are intimately connected with the progress of the severer sciences... as we

50 The contents of this and the next paragraph were added in the first edition.

51 This chapter is an amplification of the last two long paragraphs just preceding the "Conclusion" of the introductory essay. The conclusion of the essay became the last chapter of Section I of the book in the first edition, as previously noted in Chapter V.
The applied sciences derive their facts from experiments; but the reasonings, on which their chief utility depends, are the province of what is called abstract science. It has been shown, that the division of labour is no less applicable to mental productions than to those in which material bodies are concerned; and it follows, that the efforts for the improvement of its manufactures which any country can make with the greatest probability of success, must arise from the combined exertions of all those most skilled in the theory, as well as in the practice of the arts; each labouring in that department for which his natural capacity and acquired habits have rendered him most fit.

It becomes a subject fit for consideration whether it would not be politic for the state to compensate for some basic scientific endeavors.

The heads of our scientific societies should be scientists and not royalty, as has happened sometimes.

The recently formed British Association for the Advancement of Science may prove of great benefit due to the intercourse which it should encourage between the sciences and between different classes of society.

It is highly probable that in the next generation, the race of scientific men in England will spring from a class of persons altogether different from that which has hitherto scantily supplied them.

Chemical science may, in many instances, be of great importance to the manufacturer, as well as to the merchant.

When we reflect on the very small number of species of plants compared with the multitude that are known to exist, which have hitherto been cultivated, and rendered useful to man; and when we apply the same observation to the animal
world, and even to the mineral kingdom, the field that natural science opens to our views seems to be indeed unlimited. These productions of nature, varied and innumerable as they are, may each, in some future day, become the basis of extensive manufacturers, and give life, employment, and wealth, to millions of human beings. But the crude treasures perpetually exposed before our eyes, contain within them other and more variable principles. All these, likewise, in their numberless combinations, which ages of labour and research can never exhaust, may be destined to furnish, in perpetual succession, new sources of our wealth and of our happiness. The further we advance from the origin of our knowledge, the greater it becomes, and the greater power it bestows upon its cultivators, to add new fields to its dominions.

The experience of the past, has stamped with the indelible character of truth, the maxim, that "Knowledge is power."

When time shall have revealed the future progress of our race, those laws which are now obscurely indicated, will then become distinctly apparent; and it may possibly be found that the dominion of mind over the material world advances with an ever-accelerating force.

Evolution of Section II

There were many changes in contents of this second part of On the Economy of Machinery and Manufactures as it evolved from the introductory essay to the first edition. Further modifications were made in the second edition. Following this, however, no significant changes were made in the third or fourth editions.

For the most part these changes increasingly modified or qualified the theoretical principles so that they might more nearly conform to actual practice. A summary of these modifications follows.

One idea added to the first edition was the emphasis placed on the importance of collecting statistical data in order to verify
principles relating to economics and manufacturing. Babbage not only quoted many appropriate statistics in the first edition, but in the second edition he further emphasized the importance of statistics and continued to make suggestions as to where more statistics might be collected for plotting as useful curves.

Changes in the second section emphasized the inductive approach and moved away from the predominant deductive economics of the time. The limitations upon the deductive concepts were much more fully stated in the first edition than in the introductory essay and sometimes further modified in the second edition. Also, in the first edition more emphasis was placed on the part money played in the economy; in the second edition an excellent chapter was added on the monetary system of the time.

Some of the other topics added to the first edition were the following: distinction between making and manufacturing, problems of over-manufacturing, inquiries necessary before beginning to manufacture articles, discussion of strikes, and possibilities of limited partnerships. In the second edition, besides continuing to add illustrations, Babbage added topics on the following: connecting the worker's name to the product, right of government to regulate laws of work of children, advantage of machinery exportation, and effect of machinery in reducing demand for labor.

Some topics, such as the following, were separated from other topics and presented separately in the first edition and after.
They were: influence of verification on price, influence of durability on price, raw material and labor statistics, division of mental labour, contriving machinery, and various aspects of combinations.

The idea of profit sharing was presented in the introductory essay, amplified in the first edition, then presented separately and further explained in the second edition.

A comparison between the changes made in Section I and those made in Section II shows that the great majority of them occurred in the contents of Section II. Thus, the major differences in content between the "Introductory View on the Principles of Manufactures" and On the Economy of Machinery and Manufactures was in the second part, which related to the political economy of the subject.

Chapter Summary

The second section of On the Economy of Machinery and Manufactures was larger, underwent more changes, and contained more industrial management concepts than the first section. This section is concerned with both the political and interior economy of factories, for the economic principles which regulate the application of machinery and govern the interior of great factories are just as essential as mechanical principles.

A person who wishes to make any article for consumption must not only produce it in perfect form but must endeavor to produce it cheap to those who consume it. It is also important that the manufacture
collect data to ascertain how many additional customers will be acquired by reductions in price. Much more work is needed on statistical inquires of this nature and even approximate tables or data in the form of a curve might be of service.

If a maker wishes to produce a large number of parts and become a manufacturer, he must carefully arrange the whole system of his factory so as to produce items at as small a cost as possible. If he does not, he will be driven out by competition.

A manufacturer should understand the money system since manufactured commodities are measured by standards of coinage. It is important to preserve the value of the currency as stable as possible.

The money price of an article at any one time is usually stated to depend upon the proportion between the supply and the demand; the average price to depend ultimately on the power of producing and selling with ordinary profits of capital. These principles are often modified, however, by the influence of others which follow. The cost, to the purchaser, is the price he pays for any article plus the cost of verifying the article's goodness. The facility with which goodness can be determined will often have a great affect on price.

Price is dependent on the relationship of supply and demand holds only when there are a large number of small suppliers, and the demand is from others, each of whom requires only a small quantity. Only thus can the feelings, passions, prejudices, opinions, and knowledges of both parties be averaged.
The necessity of verification is diminished if the name of each workman is connected to his work. Also, the perishability or durability of an item may influence its price.

Money price is not a good basis of comparison of value over a long period of time, but it is important that manufacturers and merchants make statistical data available from as many quarters as possible so that we may better understand the operation of commerce and test economic theories. Committees might help collect and analyze such data. The errors which arise from the absence of facts are far more numerous and more durable than those which result from unsound reasoning respecting true data.

Perhaps the most important principle on which the economy of manufacture depends, is the division of labour amongst people who perform the work. The principles on which the advantages of the division of labour depends are as follows: saving time in learning; less waste of material in learning; saving time lost in changing from one operation to another due to each operation requiring the adaptation of a new set of muscles; saving time by not changing tools or making adjustments; skill acquired by frequent repetition of the same process; suggestion encouraged in the contrivance of new tools or machinery to execute the process, such as determining the proper tool angle, etc.; and being able to purchase exactly that precise quantity of skill and force necessary for each process. To explain the application of this last advantage the process of pin making is discussed with time and cost data for each operation being tabulated.
These same principles can be advantageously applied to the division of mental labour. This is explained through the example of calculating mathematical tables. The ideas can be applied to other works, as in the example of mining. Here duties have been judiciously distributed to a manager, underground captains, purser, chief pitman, surface-captain, head carpenter, foremen of smiths, materials-man, and roper.

Producers must continually watch their costs and expense of every process and continually reduce costs by discovering improved methods. Also, it is important to achieve the proper proportion of each type of labour required; this becomes especially true as steam power replaces the physical force of men.

Larger factories can move material at least expense; develop machinery; reduce waste of raw material; sometimes eliminate middle-men; more easily establish a reputation; and employ the desired skilled or specialized labour to do experimentation, legal work, seek raw materials, etc.

The location of large factories depends on the source of raw material, availability of fuel and power, transportation and communications, location of similar or allied factories, and reasonableness of combinations amongst workers.

Sometimes there are cases of over-manufacturing. The ramifications of this are partially explained but need much more study.

The chief questions one should study prior to commencing to manufacture any item relate to the expense of tools, machinery, and
raw materials; extent of likely demand; turn-over of circulating capital; rapidity of acceptance of new item; and real or apparent injury to other interests; and probable reaction of competition.

Many feel that the interest of workers and employer are at variance. This has many bad consequences. Although the prosperity and success of the master manufacturer is essential to the welfare of the workman, the connection is frequently too remote to be understood by the latter. It would help if the mode of payment could be connected to the success of the whole and each individual should advance as the factory produced profit. The system used in Cornish mines does some of this.

The means by which profit-sharing could be adopted are outlined for a new company. Two general principles to follow are: a considerable part of the wages should depend on profits made, and every person should be able to gain more by applying improvements to his own factory than elsewhere. Accurate accounts should be kept, reserve funds established, accurate times of each process and expenses ascertained, and payments made for appropriately suggested improvements. All persons would thus be interested in the over-all prosperity, preventing waste, mismanagement, making improvements, and obtaining only the best fellow workers. The system would have difficulties and be opposed by capitalists, but even if the percentage profit to capital were reduced its total amount would increase due to an increase of greater total profit. Also it might be difficult to
discharge a poor workman, but this could be handled by a meeting of the whole.

When contriving new machinery one should first represent the various parts in drawings. Sometime, however, direct trials and experimentation are first necessary. Too frequently there have been failures due to imperfection of drawings or early experiments. Also, too frequently one fails because the expense is too great relative to other methods. It is a maxim that the man who aspires to fame or fortune by new discoveries must be content to carefully examine the knowledge of his contemporaries.

It is proper to use tools when it is necessary to produce either cheap items, a great quantity exactly alike, or achieve speed of operation.

The time during which a machine will continue to perform will depend chiefly on its original construction, on its maintenance, and on the mass and velocity of its moving parts. Many machines are actually superseded by better ones before they wear out.

Amongst workmen of almost all classes there are certain rules or laws which govern their actions. These should be conducive to the general benefit, prevent fraud, and interfere as little as possible with the free agency of each individual. There are associations amongst workmen or masters which may be very useful; as in examples of fines, bonuses, rules, statistical surveys, work measurement, wage levels, contracts, and co-operatives. Worker grievances should not
only be removed, but every effort, which reason and kindness dictate, should be made to satisfy their own reasons and feelings.

Sometimes there are also combinations of masters against the public and if pressed above the growling point the public occasionally combines against business, such as has occurred sometimes with public utilities.

New machinery may for a time throw some labour out of employment yet soon the result is to increase the total demand for labour.

Manufactures should be concerned with taxes and legal restrictions, such as licenses, bounties, standardized sizes, monopolies, patents, limited partnerships, and child labour laws. Also, manufacturers should not be too concerned about the exportation of machinery, for foreigners need more than our machines to compete successfully.

For the best advancement of manufacturing it needs to be more closely connected to the severer sciences. Meanwhile, these sciences should improve the modes of operation. There are great potentials for the future of manufactures in many unexplored areas. Knowledge is power and the domination of mind over matter will advance with an ever accelerating force.

The preceding section two of *On the Economy of Machinery and Manufactures* evolved from part two of the introductory essay of the *Encyclopedia Metropolitana*. There were many changes in the first edition of the book and more in the second edition, but almost none in the third and fourth editions. These changes consisted primarily
of increased modification of the theoretical principles so as to con-
form more to actual practice; more emphasis on statistical data and
its importance; less deductive and more inductive approach; and added
or expanded topics.

Babbage gave this second section the most attention and included
in it most of his concepts relating to industrial management.
CHAPTER VII

INDUSTRIAL MANAGEMENT CONCEPTS IN OTHER WRITINGS OF
CHARLES BABBAGE

Introduction

The great majority of Babbage's industrial management concepts appeared in his book, *On the Economy of Machinery and Manufactures*, and were reviewed in the preceding two chapters. Some other concepts which are relevant to the historical development of management concepts did occasionally appear, however, in Babbage's other writings.

Babbage did not always direct the following ideas at industry but all sooner or later were used in the management of industry. These concepts are presented below according to their chronological appearance. They are related to preceding and succeeding writings of other people in Chapters VIII and IX. For relating these concepts to Babbage's life, see Chapters II through IV. For other ideas of Babbage which were closely analogous to later industrial management developments, see the following: Chapter II, Analytical Society; Chapter III, Expressing by Signs the Action of Machinery, Table of Logarithms, Constants of Nature and Art; Chapter IV, Statistical Societies, Tools, and Exposition of 1851.

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The Art of Observing

In the book, *Reflections on the Decline of Science in England, and of Some of its Causes*, Babbage discussed many factors which should be considered in properly making and reporting observations. On the limits of accuracy in using a stop-watch to measure small fractions of a second, he wrote,

A friend once brought me a beautifully-constructed piece of mechanism for marking minute portions of time; the three hundredth part of a second was indicated by it. It was a kind of watch, with a pin for stopping one of the hands. I proposed that we should each endeavor to stop it twenty times in succession at the same point. We were both equally unpracticed, and our first endeavors showed that we could not be confident of the twentieth part of a second. In fact, both the time occupied in causing the extremities of the fingers to obey the volition, as well as the time employed in compressing the flesh before the fingers acted on the stop, appeared to influence the accuracy of our observations. From some few experiments I made I thought I perceived that the rapidity of the transmission of the effects of the will depended on the state of fatigue or health of the body. If any one were to make experiments on this subject, it might be interesting to compare the rapidity of the transmission of volition in different persons with the time occupied in obliterating an impression made on one of the senses of the same persons.

On the Principles of Tools for Turning and Planing Metals

Babbage did a great deal of work on the use and construction of tools but left only one paper on the subject. It appeared in Charles Holtzapffel's book, *Turning and Mechanical Manipulation*. This

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3 Ibid., p. 173.

"Paper on the Principles of Tools for Turning and Planing Metals," as well as the following description and drawings of his tools by Holtzapffel (Note AT), are of sufficient merit to be photostatically reproduced in the following pages.

Holtzapffel introduced this article in the appendix of his book as follows,

The formation of the tools used for turning and planing the metals is a subject of very great importance to the practical engineer, as it is indeed only when the mathematical principles upon which such tools act, are closely followed by the workman, that they produce their best effects. With a full conviction of the advantages which result when theory and practice are thus associated, the author has to congratulate himself on being able to present to his readers, two original papers; respectively written on the subject of the principles of tools for turning and planing metals, by Charles Babbage, Esq., F. R. S., &c., and Professor Willis, A. M., F. R. S., &c., both distinguished by their high mathematical attainments, and their intimate practical experience in the use of tools.5


Steel of various degrees of temper and under various forms, is almost universally employed for cutting metals. Before deciding on the forms of the different tools it is desirable to inquire into the principles on which their cutting edges act, and to assign special names to certain angles on the relations of which to each other, and to the metals upon which they are used their perfection mainly depends.

In fig. 903, $c$ is a cylinder of steel or other metal, and $T$ is a planing or turning tool acting upon it at the point $a$. $A c$ is a horizontal line passing through the center $c$, and the cutting point $a$. $B a$, is a line passing through the cutting point $a$ and along the upper plane $b a$, of the cutting tool $T$. $C a$, is a line passing through the cutting point $a$ and along the front plane $c a$, of the cutting tool. $D a$, is a line from the cutting point $a$, at right angles to the radius $c a$.

The angle $D a C$, may be called the angle of relief, because, by increasing it, the friction of that face of the tool upon the work is diminished.

The angle $C a b$, may be called the angle of the tool.

The angle $B a A$, may be called the angle of escape, because the matter cut away by the tool escapes along it.

The forces to be overcome in cutting a thin shaving of metal from a cylinder or from a flat surface are of two kinds,

1st. It is necessary to tear along the whole line of section each atom from the opposite one to which it was attached. The force required for this purpose will obviously be proportioned to the length of the cutting edge of the tool, and dependent on the nature of the metal acted upon. But it will be quite independent of the thickness of the part removed.

2nd. The shaving cut off by the tool must in order to get out of its way, be bent or even curled round into a spiral. This second force is often considerable, and when thick cuts are taken, is usually far larger than the former force. If the bending were of small extent, then the force to be exerted would vary as the square of the thickness of the shaving multiplied by some constant, dependent on the nature
APPENDIX—NOTE AS.

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of the metal operated upon. But the bending very frequently proceeds to such an extent that the shaving itself is broken at very short intervals, and some shavings of iron and steel present a continued series of fractures not quite running through, but yet so complete, that it is impossible even with the most careful annealing to unwind the spiral. This partial severance of the atoms in the shaving itself, will require for its accomplishment a considerable exertion of force. The law by which this force increases with the thickness most probably embraces higher powers than the first and second, and may be assumed thus

\[ \text{force} = a + b t + c t^2 + d t^3 + \]

For the present illustration it is unnecessary to consider more terms than those already more particularly explained, namely the constant force, and that which varies as the square of the thickness of the shaving.

If therefore, \( t \) be the thickness of the shaving, and \( A \) and \( B \) two constants, we shall find amongst the forces required for the separation of the shaving the two terms.

\[ A + Bt^2 \]

where \( A \) and \( B \) depend upon the nature of the metal acted upon.

We may learn from this expression, even without being acquainted with the values of the constants \( A \) and \( B \), that the force required to remove the same thickness of metal, may vary considerably according to the manner in which it is effected.

For example. If a layer of metal of the thickness of 2 \( t \) is to be removed. It may be done at two successive cuts, and the force required will be equal to

\[ 2A + 2Bt^2 \]

But the same might have been accomplished at one cut when the force expended would have been

\[ A + 4Bt^2 \]

Now the force required for the two cuts, will always be less than the force required for making one cut, if \( t^2 > \frac{A}{2B} \)

For let \( t^2 = \frac{A}{2B} + v \) then

Force for two cuts

\[ = 2A + 2B \left( \frac{A}{2B} + v \right) = 3A + 2Bv \]

Force for one cut of twice the thickness

\[ = A + 4B \left( \frac{A}{2B} + v \right) = 3A + 4Bv. \]

which former is always smaller than the latter force by the quantity 2Bv.

In the same manner it may be proved that if

\[ t^2 > \frac{A}{\pi B} \] or \( t^2 = \frac{A}{\pi B} + v \)

it will always require less force to make \( n \) separate slices, than to cut one slice of \( n \) times the thickness for

Force for \( n \) slices

\[ = nA + nB \left( \frac{A}{nB} + v \right) = (n + 1)A + nBv \]

Force for one slice of \( n \) times the thickness

\[ = A + nB \left( \frac{A}{nB} + v \right) = (n + 1)A + nBv \]

which former force is always less than the latter by the quantity of \( (n^2 - n)Bv \)

The angle of relief should always be very small, because the point \( a \) will in that case have its support nearly in a line directly opposed to that force acting upon it.
APPENDIX—NOTE AS.

If a tool either for planing or for turning is defectively formed, or if it is presented to its work in such a manner that it has a tendency to dig into it; then a very small angle of relief, in addition to a long back, will in some measure counteract this defect.

The smaller the angle of the tool, the less will be the force necessary for its use. But this advantage of a small angle is counterbalanced by the weakness which it produces in the support of the cutting point. There is also another disadvantage in making the angle of the tool smaller than the escape of the shaving requires; for the point of the tool being in immediate connection with a smaller mass of metal, will not so quickly get rid of the heat it acquires from the operation of cutting, as it would if it formed part of a larger mass.

The angle of escape $A a B$ is of great importance and it varies with the nature of the material to be acted upon. If this angle is very small the action of the tool is that of scraping rather than of cutting, and the material removed approaches the form of a powder. However, the material is very flexible and cohesive, in that case shavings may be removed. The angle $A$ have found best for cutting steel is about $27^\circ$, but a series of experiments upon this subject is much required.

After the form of the cutting tool is decided upon, the next important point to be considered is the manner of its application. The principle which is usually stated for turning tools is, that the point of the tool should be nearly on a level with the axis of the matter to be turned, or rather that it should be very slightly below it. This rule when applied to the greater number of tools and tool-holders is calculated to mislead. Before applying the correct rule it is necessary to consider in each tool or tool-holder, what is the situation of that point around which the cutting point of the tool will turn when any force is put upon the tool. Let this point be called the center of flexure. Then the correct rule is, that the center of flexure should always be above the line joining the center of the work and the cutting point.

On looking at fig. 283 A c, is the line joining the cutting point $a$ and the center of the work $c$. By making the tool weak about $Q$ that point becomes the center on which the point $a$ will bend when any unusual force occurs. On the occurrence of any such unusual force arising from any pin or point of unequal density in the matter cut, the point of the tool $a$, by bending around the center $Q$ will dig deeper into the work and cause some part of the apparatus to give way or break.

If on the other hand the point $P$ is that around which the point of the tool when resisted tends to turn, then since this point is above the line joining the cutting point and the center of the work, the tendency of the additional strain on the point is to make it sink less deeply into the work, and consequently to relieve itself from the force opposed to it.

Fortunately the position of this point can always be commanded, for it is always possible, by cutting away matter, to make one particular part weak. This is indeed a circumstance too frequently neglected in the construction of machinery. Every piece of mechanism exposed to considerable force is liable to fracture, and it is always desirable to direct it to break at some one particular point if any unexpected strain occurs. In many cases where danger may arise from the interference of the broken part with the rest of the machinery this arrangement is essential. In all cases it is economical, because by making the breaking, if it occur, at a selected spot, provision may be made of duplicate parts and the delay arising from stopping the machine be avoided.

The results of the preceding inquiry would lead to considerable changes in the forms of tools generally used in cutting metals, and as the time employed in taking
a cut is usually equal whether the shaving be thick or thin, the saving in power by taking thin cuts separately would be accompanied by a considerable expense of time. This however need not be the case if proper tool-holders are employed, in conformity with the following several conditions: thus

The tool-holders should be so contrived as to have several cutters successively removing equal cuts.—The cutting edges should be finely adjusted to the work.—The steel of which the cutters are formed should be of the best kind, and after it is once hardened should never again be submitted to that process.—The form and position of the cutter should be such that it may, when broken or blunted, be easily ground, having but one or at the utmost but two faces requiring grinding.—It is desirable that when being ground it should be fixed into some temporary handle, in order that it may always be ground to the same cutting angles.—The cutters should be very securely, but also very simply tightened in their places.—The center of flexure of the cutter should, in turning, be above the line joining the center of the work and the cutting point;—whilst in planing the center of flexure should lie in advance of a line perpendicular at the cutting point to the surface of the work planed. Examples of some tool-holders of this kind will be given subsequently.

The effects of such improved tools would be to diminish greatly the strain put upon lathes and planing machines, and consequently to enable them to turn out better work in the same time and at a less expense of power: whilst the machines themselves so used would retain their adjustments much longer without reparation.

Note A.T.—To follow Note A.S at foot of page 581.

(The author’s description of Tools and Tool-holders for turning and planing metal, constructed by C. Babbage, Esq., F.R.S.)

In the course of the investigation which led Mr. Babbage to write the foregoing paper, he constructed various experimental tool-holders, a part of the more successful of which I shall now attempt to describe, beginning with those in which a single

Fig. 984.

Fig. 985.

cutter is used. The figures are one-fourth of the size of the actual tools, but the proportions of which may of course be enlarged or reduced according to circumstances.
Appendix—Note at.

Fig. 904 represents the perspective view, fig. 905 the plan, and a b c d e the details of Mr. Babage's tool-holder, for the general purposes both of turning and planing metal: the tool itself c, being simply a short rectangular piece of steel cut off from the end of a long bar, and ground at the end with one chamfer at about 60 degrees with the length of the blade. The stock is cast of gun-metal and of a cranked form, as seen in fig. 904, the end being pierced with a vertical hole, in which is fitted the bolt a, having a long diametrical mortise to admit the tool freely as shown, and a nut and washer c, below to blind all the parts together. The bolt a, passes through two circular wedges b and d, inclined at the angle 27° on their internal faces, and loosely united by steadying pins; the lower circular wedge has a diametrical inclined mortise to serve as the seat for the tool, and which is grasped by the margins or walls of the wedges, when the bolt and nut are tightened.

Sometimes the cutter lies centrally to the shaft of the holder, as shown in fig. 904, and also by the central dotted line in the plan, the vertical branch of the holder is pierced with a mortise, then to receive the superabundant length of the steel cutter; but at other times the cutter is inclined about 45° in either direction, as represented in the plan, fig. 905, and the cutter then just escapes the stock through a little notch filed for the purpose.

The one inclined position has been represented in the plan, fig. 905, and in this case the point of the cutter lies in a very favourable position for turning either cylindrical or plane surfaces, as the cutter stands in advance of the stock, and may proceed into an internal angle, such as the joining of a mass composed as it were of two cylindrical blocks of different diameters. The tool when simply bevelled, or ground with one chamfer, will not perfect the inner angle of the work on both faces, but which may be done if the tool is ground with two faces, or as a pointed tool meeting at an angle a little less than 90°.

The figure also represents a very useful addition, applicable to all the tool-holders and slide-rests for metal turning, namely a little eye-shade, which is no more than a small piece of window glass, attached either to the tool-holder or any part of the rest, in a spring clamp which retains it at about an inclination of 45 or 50 degrees, so as to be nearly at right angles to the line proceeding from the point of the tool to the eye of the workman, which is effectually shields from injury. This simple contrivance, which may be readily added to any slide-rest, enables the workman narrowly to inspect the course and progress of the tool, and yet defends his eye completely from the shavings.

Fig. 906 represents the perspective view, and fig. 907 the end view, (full size,) of Mr. Babage's tool holder for internal works, and the small parts are shown detached, also full size.

The cutters c are short pieces cut off from a bar of steel, fluted in the planing machine, to give that which Mr. Babage has described as the angle of relief, and they are sharpened almost exclusively at the end, nearly square across or slightly chamfered or rounded at the corner. This tool-holder is made of steel, the end is turned cylindrical, and a cleft is sawn with a thick circular cutter or saw, down one side nearly to the axis, and entirely across the end to the depth of about one diameter and a half.
In the end view fig. 987, c represents the cutter, b the block against which the cutter rests, and the screw that passes through b, and holds the several parts in contact. The tool may be made to cut on the right or left hand side at pleasure, as c and b each reverse. To enable the cutter to resist being drawn out, by the force of the cutting action, the small square wire, represented black, is added, this square wire fits a groove planed out in the tool holder, and lies in the flute of the cutter so as to secure it.

In this internal cutting tool as in all others of similar kind, a hole must be drilled or otherwise made in the work to admit the shaft of the tool, before it can be used, and from the contracted measure of the tools used for turning the inner surfaces of small apertures, the most suitable angles cannot be generally given to the internal tools.

Figs. 988 and 989 represent in the entire and dissected states, one of several tools contrived by Mr. Dallago, for turning wood by means of the slide rest. A small part of the end of the gun metal tool holder is inclined to the stem, and the extreme end is filed convex to fit the concave side of the gouge c, which is ground on the outside, exactly as usual with a gouge used by hand. The cutter is retained by means of the strap d, which embraces the cutter, and also two little blocks a, and b fitted together with a chamfered joint, so that the middle piece, which is carried down by the central binding screw, acts as a powerful wedge, and fills out the space within the loop, consequently the tool is grasped with considerable firmness against the rounded end of the holder, even when the pressure of the screw is very moderate. The screw requires a groove below its head, and the wedge b, a corresponding pin or key, that it may be raised to release the tool when the screw is unwound.

In some of these tools the cutter is circular as a gouge, in others straight as a chisel, or angular as a pointed tool, and of these three variations, some have bent shafts the ends of which not only dip downwards, as shown in the side views figs. 988 and 989, but are also inclined horizontally at an angle of 45° as in fig. 990, in order to produce the same effect as the inclined position of fig. 985, and enable the same tool to serve alike for turning cylindrical or plane surfaces at the one fixing. The whole of these cutters for wood act in a vigorous and efficient manner.

I shall now say a few words on Mr. Dallago's notions of the employment of cutting tools with many points, so that the work may be equally divided among all the points.
The most simple case quoted by Mr. Babbage, is that of the screw tap, in which to carry out his principle, he cuts 6 or 7 longitudinal grooves instead of three only, the faces of which grooves are undercut or inclined to the radius, although not fully to the approved angle of 27°; they more resemble those taps called by workmen original taps, shown in figures 550 and 551, page 591, but they nevertheless answer for tapping and screwing the finer class of work, as they produce true threads and work freely. The circular tops of the threads are as usual a little cleared with the file, unto near the cutting points, and in the larger sizes of these taps the flutes are undercut to admit of their being sharpened on a revolving lap.

Another example quoted by Mr. Babbage is that of Messrs. Whitworth's key-way cutter, for making the internal grooves in the holes of wheels, for the keys by which they are fixed upon their cylindrical shafts. The cutter is a cylindrical rod of steel, through which are made about ten or a dozen rectangular mortises, placed at equal distances and in a right line. Every mortise is fitted with a small steel cutter, the sides of which are made exactly true in the engineer's planing machine; the first cutter is sharpened so as scarcely to project beyond the surface of the cylindrical bar, the second projects a little more than the first, and so on to the last, the projection of which equals the full depth of the key-way. When used, the bar is first put into the hole of the wheel, and which it should exactly fit, and the bar is steadily pushed quite through the hole of the wheel or pulley, by aid of the steady movement of an appropriate screw press.

This mode of action always cuts the key-way parallel and not taper as frequently wanted. From the subdivision of the work among the many cutters, the work is well done, and almost without injury to the cutters, which should be sufficiently close together, that the succeeding cutter may enter the groove, before the previous one has passed through the same; in other words, the interval between the cutters should be always less than the thickness through the boss of the wheel. The cutters after having been sharpened, are set forward by aid of little screws fitted in a thin bar, inlaid in a chamfered groove extending the whole length of the cutters.

Figs. 991 and 992, represent Mr. Babbage's tool holder with many blades for the planing machine. This tool holder consists of two parallel bars of gun-metal, united to cross pieces at the ends, so as to form a narrow central cleft; the side bars are pierced with several holes which receive as many pins, that constitute the centers upon which a series of short parallel blades are jointed to the holder. When in use, the blades are separated by parallel slips of brass, and at the left extremity is a block to which is given the inclination of 27°; and the end screw being fastened the whole of the blades are fixed at that angle; Mr. Babbage says in making another tool holder of this kind he would cast the holder in one piece, and tighten the cutters by the method of the screw and wedge a, b, fig. 988.

In order to sharpen the cutters, the brass separating pieces and the angle block at the end are removed, and all the flat pieces then fall down so that their chamfered ends lie in a straight line; when thus fixed by the end screw, their chamfers are all ground at once upon a lap; on the re-insertion of the brass plates, the tools bristle up like so many saw teeth after the manner shown. The tool is fixed in the planing machine at such an inclination, that the first cutter penetrates but a little way,
and every succeeding cutter penetrates more and more unto the required degree, owing to the inclined position of the tool-holder; the difference in elevation or projection of its two ends, being exactly equal to the intended thickness of the shaving to be removed, and the two tails of the tool-holder enable each end of the same to be securely grasped in the planing machine. (See first paragraph, page 982.)

Fig 993, a face-cutter for the lathe, is the last of these tools which Mr. Babbage's occupations have given him leisure to devise. The circular block is screwed to the lathe as an ordinary chuck, and on its cylindrical surface are cut 10 wedge-form grooves or notches, the one side of every notch is exactly on a diameter, the other side of the notch is inclined a few degrees, and fitted with a parallel steel blade, and a gun metal wedge; the several wedges are sent forward by tail screws, tapped through a ring screwed on the back part of the chuck or otherwise attached.

To sharpen the blades they are removed from the chuck and placed in the rhomboidal cavity of a tool-holder shown in perspective in fig. 995, and in plan in fig. 996; the sides of the cavity are parallel and in pairs, but inclined in both directions to the angles at which the cutters are ground upon a revolving lap; the horizontal angle seen in 996 is 24 degrees, the vertical is 16. By means of this holder the chamfered ends of the cutters are all thrown into one plane, and the sides of the cutters into another plane, and secured by two equal or folding wedges, the ends and sides of all the cutters are then ground en masse.

When replaced in the chuck a distance plate with a central projection or boss, is first fixed to the end of the chuck, the cutters are allowed to rest in contact with this plate, and on the screws being tightened, every cutter becomes fixed by its wedge, and the distance plate ensures the ends of the cutters lying on one plane, and as much in advance of the end of the chuck, as the space between the chuck and the reduced margin of the distance plate.

This circular cutter with removable blades, may be viewed as a miniature and refinement, of some of the large boring tools and cutters with loose blades, figs. 516 and 517, pages 569 and 571; and the tool here shown has been extensively used by Mr. Babbage in facing all kinds of rectilinear pieces, which are at the time fixed in the slide rest, or in a universal chuck with screw jaws attached to the slide rest, by means of which the works are carried past the end or face of the slowly revolving cutter, which serves for several of the metals including steel, but the most effectively for brass and gun metal.
A Fair Day's Wage for a Fair Day's Work

In 1848, Babbage published a 24-page pamphlet, "Thoughts on the Principle of Taxation, with reference to A Property Tax and Its Exceptions." This pamphlet was slightly expanded and republished in 1851, 1852 and 1907. It contained Babbage's opinions on property and income tax and is not too relevant to this dissertation. In the following passage, however, he included an italicized phrase which is identical, in part, with a phrase common to later writings in management.

In discussing indirect taxation, Babbage told an anecdote which started as follows,

An Irish proprietor, whose country residence was much frequented by beggars, resolved to establish a test for discriminating between the idle and the industrious, and also to obtain some small return for the alms he was in the habit of bestowing. He accordingly added to the pump by which the upper part of his house was supplied with water, a piece of mechanism so contrived, that at the end of a certain number of strokes of the pump-handle, a penny fell out from an aperture to repay the labourer for his work. This was so arranged, that labourers who continued at the work, obtained very nearly the usual daily wages of labour in that part of the country. The idlest of the vagabonds of course refused this new labour test; but the greater part of the beggars, whose constant tale was that "they could not earn a fair day's wages for a fair day's work," after earning a few pence, usually went away cursing the hardness of their taskmaster.

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7 Ibid., p. 20.
Science of Shoveling

In management literature the "science of shoveling" has been used as a frequent illustration of the application of the scientific method, and Fredrick W. Taylor's experiments with shoveling at Bethlehem Steel Company have "become classic in the field of management." Unfortunately for the history of management, the general impression has been given that no one thought of studying such things as the art of shoveling until F. W. Taylor did his experiments. Nothing could be further from the truth, as indicated below and in Chapters VIII and IX.

In the introductory chapter of the book, The Exposition of 1851; or Views of the Industry, the Science, and the Government of England, Babbage explained how the art of shoveling could be used to explain ways of improving operations which are frequently repeated.

One of the most frequent sources of mistaken views in economical science, arises from confounding the nature of universal with that of general principles.

Universal principles, such as the fact that every number ending in the figure five is itself divisible by five, rarely occur except in the exact sciences. Universal principles are those which do not admit of a single exception.

General principles are those which are much more frequently obeyed than violated. Thus it is generally true that men will be governed by what they believe to be their interest.

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Yet it is certainly true that many individuals will at times be governed by their passions, others by their caprice, others by entirely benevolent motives;...Notwithstanding, however, all the exceptions we may meet with, it is impossible to take any just views of society without the admission of general principles, and on such grounds they will be used in these pages.

Again, it is admitted as a general principle that each man is the best judge of his own wants and of his own interest.

In taking a comprehensive view of any subject, it is very desirable to throw into the shade all its minor points; but in estimating the consequences of any set of facts, there is another condition which must be fulfilled, before we can arrive at accurate conclusions. If we are about to neglect a cause on account of its apparent insignificance, it is essential that it should not be one of frequent recurrence. Thus, if a labourer inconsiderately lift his shovel but an inch or two more than is necessary to throw its load into his barrow, although the exertion of force is trivial in each instance, its repeated occurrence during the whole day, will produce at its conclusion a very sensible difference either in fatigue or in the amount of work done...To dwell upon small affairs which are isolated, is not the province of a statesman; but to integrate the effect of their constant recurrence is worthy of the greatest.

One of the most important processes in all inquiry, is to divide the subject to be considered into as many different questions as it will admit of, and then to examine each separately, or in other words to suppose that each single cause successively varies whilst all the others remain constant.

But this most obvious doctrine of common sense has frequently been contested in questions of economical science, and has been often characterized as theoretical, and as entirely inapplicable to the affairs of life. It is certain that very little progress can be made in any subject without this aid, and it is hopeless for those whose minds are incapable of mastering the simpler questions, ever to institute successfully an investigation into their united action.

A familiar illustration will explain this better. Two men are making an excavation, removing the earth in the usual way with spades and wheelbarrows.
One of these men, $Q$, does more work than his companion $P$, and if an inquiry is made, Why is this so? the usual reply would be that $Q$ is either stronger, more active, or more skillful than $P$.

Now it is the third of these qualifications which is the most important, because if $Q$ were inferior even both in strength and in activity, he might yet by means of his skill perform a greater quantity of work without fatigue.

He might have ascertained that a given weight of earth raised at each shovelfull, together with a certain number of shovelfulls per hour, would be more advantageous for his strength than any other such combination.

That a shovel of a certain weight, size, and form would fatigue him less than those of a different construction.

That if its handle were two or three inches longer than he required, its additional weight would at the end of the day have been uselessly lifted many hundreds of times.

That if each spadeful of earth were lifted but an inch or two above the barrow, beyond what was necessary, a still greater waste of force would arise.

That if the barrel itself had its wheel at a distance beyond the center of its load, it would be more fatiguing to draw.

That if the barrow had upright sides, it would require more exertion to turn out its load than if its sides were much inclined.

Thus although $Q$ might have less strength and less activity than $P$, he might yet by skill and practice, have arrived at some combination of these tools which should enable him with less fatigue to do more daily work than $P$.

But in order to have arrived at this degree of skill, $Q$ must when a boy have been taught to examine separately the consequences of any defect or inconvenience in the parts of the tools he was to use in after life, or in the modes of using them. If not so taught, he must have arrived at the same knowledge by the slower and more painful effort of his own reflections.

In either case, he would be able to communicate his knowledge to his friends or his children; and if circumstances
induced or obliged him to enter upon a new trade, he would naturally apply those principles to his new tools. Indeed, whatever subject might be presented to a mind thus trained, such habits of inquiry would most probably be applied to its examination. Thus, by the early education of his reasoning faculties on the trade by which he is to subsist, he would not only render his own labour more productive, but would have his mind better prepared for the reception of other truths.

Chapter Summary

There are few of Babbage's writings; other than the book On the Economy of Machinery and Manufactures, which contained industrial management concepts. The few that are important are presented in this chapter.

In discussing the art of observing Babbage pointed out the limitation of using a stop-watch to measure too small an interval of time.

In his "Paper on the Principles of Tools for Turning and Planing Metals" Babbage indicated some of the forces involved in cutting metals; the importance of various tool angles; the proper point of application of a tool; the importance of good tool holders; and the need for correct hardening and sharpening of tools. Holtzapffel then described Babbage's tool holders, new tools, tool sharpening mechanisms, and safety devices. (See Chapter IV "Tools" for further information on tools.)

In an anecdote illustrating a pamphlet on taxation, Babbage italicized the phrase, "they could not earn a fair day's wage for a fair day's work." His illustration did not apply to management but a similar phrase later became popular in the scientific management movement.
In explaining how a frequently repeated operation could be improved, Babbage outlined possible considerations in the art of shoveling. Babbage suggested considering the weight of the load; number of shovelfulls per hour; shovel weight, size, and form; handle length; height lifted; wheelbarrow design; and fatigue. For carrying out such an experiment years later F. W. Taylor has been credited with too much originality. (See Chapters VIII, IX, and X.)
CHAPTER VIII

PEOPLE AND CIRCUMSTANCES
INFLUENCING BABBAGE'S WRITINGS

Introduction

As noted earlier, the objective of this dissertation is to evaluate the contributions made by Charles Babbage to the historical development of industrial management concepts. In order to properly achieve this objective, it is essential to have some understanding of the development of industrial management concepts prior to Babbage and to study the people and circumstances which influenced Babbage's writings. Part of this was accomplished in the study of Babbage's life in Chapters II-IV. This present chapter continues this background study and covers those developments which would have necessitated too much digressing from the main events of Babbage's life to have been adequately covered in earlier chapters.

Abundance of Earlier Material

Babbage's works have been characterized as being far in advance of their time and the first to study industrial organization from the scientific standpoint. 1 The classical interpretation of management history has taught that very little study was made of industrial

management problems before the end of the nineteenth century and consequently practically none prior to Babbage. If this dissertation were designed to be just a hymn of praise of Charles Babbage it would be easy to accept these conclusions.

1 cont.


Research for this chapter, however, found the preceding analysis to be completely contrary to fact. Actually, a great many significant studies of industrial management problems were made prior to Babbage and some of these definitely influenced Babbage's work. The ideas of these earlier studies were not always under the same titles as used later, as Drury and others expected them to be, but plenty of earlier material is available if the researcher will dig for it.\(^3\) There is

\begin{itemize}
\item Drury, op. cit., pp. 20 ff. This work is a good example of the gross errors which have been made too frequently in studying the historical development of industrial management concepts. Drury thought he "statistically demonstrated" the revolutionary growth of new ideas by tabulating the articles using the terms "scientific management" and "efficiency" after 1910. All he actually proved was the increased use of these terms and not a sudden growth of new concepts. There is no evidence in studies such as this one to indicate that even a reasonable attempt was made to seek out earlier concepts.
\end{itemize}

The bibliographies of management literature have made similar mistakes. See:

enough industrial management information prior to Babbage to fill many dissertations. So many unrecognized, important earlier developments in management literature were uncovered in this research that it became necessary for this chapter to limit the presentation to only some of the earlier industrial management developments and to only some of the factors which influenced Babbage. The result is

3 cont.


An adequate listing of all potential sources of management concepts prior to the time of Babbage is beyond the bounds of this dissertation. However, the following is an indication of a few sources where some of this material may be found:

1. Journals and publications of the various European scientific societies.
2. European and American scientific and popular magazines.
3. Encyclopedias.

Also see books such as mentioned in the bibliographies of the following works:

that this chapter is only a sampling of developments previous to Babbage's *On the Economy of Machinery and Manufactures.*

Babbage's great breadth of interest and study enabled him to gather information from such areas as mechanics, economics, statistics, and physical sciences. House of Commons Committee

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1 cont.


5 Babbage, Charles *On the Economy of Machinery and Manufactures.* London: Charles Knight, 1832.

One of the important sources of information about the possible background of Babbage's ideas is the catalogue of his excellent library. It is estimated to have contained over two thousand volumes. Upon Babbage's death the library was purchased by the Earl of Crawford and donated to the Edinburgh Royal Observatory in 1888. A search of these books of Babbage might provide even more information on Babbage. Ref. Southeby, Wilkinson, and Hodge *Mathematical and Scientific Library of the Late Charles Babbage.* London: C. F. Hodgson & Son, 1872; and *Catalogue of the Crawford Library of the Royal Observatory.* Edinburgh: Milne and Hutchinson, 1890.

Another possible source of information on Babbage which was not examined for this dissertation is the Babbage Papers which are understood to be in the Museum of the History of Science, Old Asholean Building, Broad Street, Oxford, England. Ref. Personal letter from Miss Elizabeth M. Buxton, October 12, 1954.

6 Much of Section 1 of *On the Economy of Machinery and Manufactures* was similar to parts of works on mechanics or natural philosophy.

7 Babbage knew well at least the following economists of his time: Nassau Senior, Richard Jones, T. R. Malthus, and Harriet Martineau (popular writer). See Chapter I.

8 See Chapter IV, "Statistical Societies."

9 He was a member of many scientific societies and a recognized scientist. See Chapters II-IV.
This chapter makes no pretense to cover all these important areas but does review some of those which shed light on the history of our industrial management concepts; it indicates how Babbage was truly a product of his time.

It is hoped that the following information may help provide a start to a better historical perspective of industrial management concepts, for it is inconceivable that anyone who studies material such as the following cannot help but cry out in protest against the classical teachings of management history.

A Fair Day's Work

The concept of a fair day's work was selected for review in this chapter because: (1) it was one to which Babbage referred, both directly and indirectly, (2) it was one which received a great deal of attention in later industrial management writings, (3) it indicated the type of work done prior to Babbage, and (4) it provided information about allied subjects.

Studies of a fair day's work, or how much work a man could be expected to do in a day, were done prior to Babbage's writing


On the Economy of Machinery and Manufactures by such men as the following: De la Hire, Bernoulli, Desaguliers, Coulomb, Robinson, Buchanan, Gerstner, Welcher, Nordwall, Vauban, Christian, Nicholson, Emerson, Leslie, Hachette, Morisot, Hassenfratz, Navier.


Amontons, Bouguer, Euler, Schulze, Sauveur, Belidor, and others. Not only did the above men study and experiment as to how much work men could be expected to do in a day but many of them intended their results to be useful to industry.

As an example of earlier work in this area of a fair day's work note that in the latter half of the seventeenth century "the Académie des Sciences, invited scholars to study the operations done by the worker in his workshop, in order to help them do a better job." Probably as a result of this, De la Hire presented his paper, "Examen de la Force de l'Homme" before the Académie in 1699. This study was largely of men lifting, carrying, and pulling weights and an analysis of why the force exerted depended upon the method of using human strength.

The most famous early experiments and observations on the amount of work men could do in a day were made by M. Charles Augustus Coulomb, the same French doctor who proved Coulomb's laws of electricity. The observations of Coulomb were first published in 1781.


20 For the benefit of other researchers it should be noted that this topic was frequently under the heading of "animal strength."

21 Bourdel, op. cit., p. 323.


23 Coulomb, op. cit.
and then republished in 1809 and 1821. Unfortunately for the history of industrial management concepts, this work is not known to have been translated into English. If it had been, the famous pig iron and shoveling experiments of F. W. Taylor might not have received the undue recognition they have and Taylor's claim to great originality might have been unmasked long ago.

The length of Coulomb's article precludes full translation here but the following are translated excerpts indicating some of his ideas.

There are two things to be distinguished in the work of men and animals—the effect which their energy can produce when applied to a machine and the fatigue which they undergo in producing this effect. To obtain the most from a man's energy it is necessary to increase the effect without increasing the fatigue; that is to say, supposing that we have a formula which represents the effect and another the fatigue, to obtain the greatest advantage of animal energy it is necessary that the effect divided by the fatigue is at a maximum.

Thus the whole question reduces itself to a search for a way to combine the different degrees of force, of speed, and of time, so that a man, with equal fatigue may furnish the greatest quantity of action.

Bernoulli, who discussed this question...evaluates the daily work of men, in all types of work, at a weight of 1,728,000 pounds raised to one foot...

24 Southey, op. cit., Item 48 under "Mechanics."

25 There has been a great deal written on this, but for an example of Taylor's own words see: Taylor, Fredrick Winslow The Principles of Scientific Management, pp. 54 ff., in Person, Harlow S. Scientific Management. New York: Harper & Brothers, 1947.

In Désaguilliers, and the majority of the authors who have needed to evaluate the action of men in the operation of machines, have adopted more or less the same results; all these authors cite experiments, but I point out the greater part of the experiments that they cite lasted only several minutes, and that men can, during several minutes' time, produce a quantity of action which they could not keep up an hour each day; thus no conclusions at all can be drawn.

This combination [of speed, force, and time] is different, as we shall see later, according to the different ways in which a man employs his energies; so that we have this result, that, as in any work which tends to furnish the greatest effect, the quantity which expresses the maximum of action relative to the fatigue should be the principle object of research which is to follow.

Concerning the quantity of action men can furnish when they climb a ramp or a stairway during a workday, with or without a weight. [Heading translated from Coulomb]

[Taking fatigue into consideration, Coulomb concluded from various experiments and observations the amount of daily work a man performed in climbing stairs, with a load and without one. From these he developed a formula to determine the maximum useful effect of a man climbing a stairway with a weight. He concluded that for maximum results a man should carry 53 kilograms per load. Comparing this with the load they sometimes carry Coulomb showed that workers cannot themselves properly conclude as to what is the proper amount to carry.]

Other chapter headings of Coulomb were as follows:

Comparison of the quantity of action men can furnish when they are traveling on a horizontal plane or without a load.

Concerning the quantity of action which men can furnish in their daily work when they transport loads in wheelbarrows.

Concerning the quantity of action which men can furnish in pile-driving, a movement which is executed when they raise the ramshead to strike and drive in the piles.

27 Compare this and later statements to F. W. Taylor's extolled law of heavy labor which merely said, "for each given pull or push on the man's arms it is possible for the workman to be under load for only a definite percentage of the day." Ref. Taylor, op. cit., p. 57.
Concerning men acting on levers

Concerning the quantity of action which men consume in their daily work when they work the earth with a spade.

There is so great a variety in the results of this type of work, which depends on the type of terrain and seasons, and even on the weather where previous work has been done, which lets the earth more or less settle down, and the roots of the plants which cover its surface...that the calculations which are to follow...should be considered only as a particular example which should serve to throw some light on the works which are analogous to it.

The laborer sunk his spade 25 centimeters into the earth and with each blow of the spade he raised an average weight of earth of 6 kilograms whose center of gravity he raised in turning it over to a height that varied a great deal, but that I thought by taking a mean measurement to be 4 decimeters. The earth although quite heavy was easily broken up, and it was only after 5 or 6 blows with the sharp edge of the spade to break the clods to level the work: he made about 20 blows with the spade per minute. The first effort to sink the spade into the ground was at a mean of 20 kilograms: when the spade had been driven in several centimeters, the energy to continue to sink it into the earth was hardly 12 kilograms.

There is an art of laboring as in all the other arts where men consume all their daily energy; the skill consists always in employing the action usefully. In the example work, the distribution of the action of the man should vary according to the state, nature of the earth, and even the season when he's doing this work; but a good worker uses all of his action in a useful manner, while a bad worker although quite vigorous, drops the upper part of his body more than is necessary to drive the spade into the earth with each blow of the spade, and not being adroit at turning over the earth, he often raises it more than is necessary, and he thus consumes in pure loss a part of his action with the result that while giving a workmanship of less quality to the earth, he works a smaller plot with equal fatigue.

In this, as in all of this, when the observer can procure the necessary elements for the establishment of the calculations of the action of the men, it is necessary to follow a good worker paid by the piece; but at the same time, in order not to influence his momentary work, he should not know that he is being observed.
It seems even, according to practice, that men in their work can, with equal fatigue, produce the quantity of daily action, by varying their speed a great deal and cutting their work by small intervals of rest.

His action was cut by intervals of rest or by work which fatigued little;...

It seems that this matter of cutting into small intervals of action and of rest the work of men who carry heavy loads, is that which is best suited to the animal economy...

...a man walked freely up a stairway, and by dropping by some means, he raised a weight equal to his own weight...he would do so much work as four men carrying the same weight on their back.28

...I beg of those who would like to repeat them [these experiments] if they don’t have time to observe the results after several days of continuous work to observe the workers at different times of the day without letting them know they are being observed. It is impossible to have pointed out too much the risk of making mistakes in calculations either for speed or for effective time of work after an observation of several minutes.

The choice of men influences a great deal the evaluation of their mean energy.

Finally, the mean quantity of action varies according to the food but above all according to the climate.

There is no doubt that Babbage knew of Coulomb’s work for he quoted it in On the Economy of Machinery and Manufactures29 and had a copy of Coulomb’s studies in his library.30 Furthermore, a comparison of Babbage’s writings on shoveling31 and Coulomb’s analysis,

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28 This probably was related to similar observations of De la Hire. Cf., op. cit.
29 Babbage, C. E conomy, op. cit., pp. 33, 118.
30 Southby, op. cit., Item 48 under "Mechanics".
31 See Chapter VII, "Science of Shoveling".
"Concerning the Quantity of Action Which Men Consume In Their Daily Work When They Work the Earth With a Spade," indicates that Babbage undoubtedly obtained his ideas on the study of shoveling either directly or indirectly from Coulomb's work.

Continuing with excerpts of other early studies of what is a fair day's work; M. Schulze, in 1873, made studies of twenty men of different size and weight in order to answer this question. He wanted to know what force men could be expected to exert in industrial applications and to test the formulae and conclusions of earlier writers. The following are some of M. Schulze's comments as were translated from the French.

Those who have had the occasion to construct machines driven by men or animals, realize how important it is to know the quantity of work that can be attributed to one or the other, in order to estimate exactly the effect which is meant to be obtained by the machine...

This table [not quoted here] proves that the size of the men employed to raise the weights vertically has considerable influence on the height to which they brought the same weight. We find that the height diminishes in a much more considerable ratio than the weight increases: and we may therefore conclude, that it is advantageous to employ large men when it becomes

32 Cf. ante.


34 Part of the following is from the translation of M. Schuelze's work in Gregory, op. cit., pp. 384-397. [This latter work first appeared in 1825 and was undoubtedly known by Babbage since Gregory and Babbage were friends and both original members of the Astronomical Society; see Chapter II.]
necessary to draw vertically from below upwards: and on the contrary, it is more advantageous to employ men of a considerable weight, when it is required to lift up loads by means of a pulley about which a cord passes, so that the workmen may draw in a vertical direction, from above downward.

These two tables [not quoted here] show that men have less power in drawing a cord before them than when they make it pass over their shoulders; they show, also, that the largest men have not always the greatest strength to hold, or to draw in a horizontal direction, by means of a cord. [Note these experiments were made on special equipment designed for this purpose]

On this same subject of a fair day's work M. Christian in his *Traite de Mécanique Industrielle* wrote the following comments. 

So the first economic rule for the use of the force of the man consists in dispensing it in a period of time long enough to permit frequent intervals of rest...

There are great differences in effects produced in the use of human beings: the number of muscles in action, which is determined by the method of application which has been chosen; the direction in which the effect takes place; the part of the body which is moving; the build and constitution of the workers; temperature of the place of work; the regularity or irregularity of the resistance to be overcome; the continuity of action or the extent of the intervals in the employment of effort or of the speed of muscular movement; the habit of working in such and such a manner or in other words, the habitual exercise of the muscles of these parts of the body; such are the principle sources of the variations which are presented by the results of man's motor action.

[When] a large portion of the muscles of a man's body are used...it is necessary to give frequent intervals of rest and to reduce the effective work of one day to two or three hours at the most. The muscles of the man are not all equally suited

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36 Compare this and the following to F. W. Taylor's law of heavy labor. *Cf. ante.*
to sustaining the action which they may have to set in motion and it takes only one tired muscle to diminish at once the force a man can dispense.

The observer is astonished at the differences which he notices between the amounts of action which are furnished by two men who seem equally strong but who are of different natures...

The temperature of the workshop or the climate causes variations more remarkable still in the amount of daily action produced.

In industrial establishments one must choose the place with the most fresh air for men who are to sustain a continuous task which exacts all their force.

But whatever may be the precautions that are taken by good arrangements to help the exertion of force of a man, one still notices striking variations in the amount of daily action dispensed, according to whether the workman is more or less habituated to the sort of work which is given him; long experience not only strengthens the muscles which are acting, but it produces also a sort of skill in the manner of dispensing the force.

It is first of all only by graduating both the effort and the speed of deployment, or by permitting frequent rest periods, that one can gain the habit of one type of work... The need for earning a salary, by fulfilling a prescribed task, sometimes puts man to the cruel necessity of overtaxing his strength, in the first periods of apprenticeship; it is the job of one who employs him to know what the workman is able to do; and what responsibility weighs on the master, if he does not see the man, but the work done!

...The solutions which one can find [the force man is really capable of] that is perhaps even reasonable to look for, are relative to a special case, to an individual, and to particular circumstances...

The movements which he [man] can quickly produce are: rectilinear movements and that of continuous rotation; the movement of rectilinear back and forth, and back and forth movement thru arcs of different sizes.

As for the continuous jobs in factories, it seems that the use of the crank should be preferred in general to any other method.
Francis Gerstner in discussing general rules for the application of animal power made statements such as the following: 37

Muscular strength, frequent practice, age, sex, and even the will to exert power, have a great influence on the effort of men, and therefore it is plain, that the absolute extent or value of this power cannot here be fixed with certainty.

It is well-known, that every man can exert a greater strength or carry a heavy burden, when the work is of no long duration, or if the burden has not far to be carried, or can soon be laid down.

Gerstner arrived at various formulae and considered such things as "How is the work to be arranged, that the expense of carrying at a fixed price for daily work, may be the least? Or if the price for carrying a Cwt. be given, how is the workman to manage his work, so as to earn the highest possible daily wages." He concluded, "The expense of transport for a hundredweight per mile is therefore smallest, where the men work with their mean velocity through the ordinary working time." 38

The preceding excerpts in this chapter show conclusively that there certainly were studies of how much work a man could do in a day long before the time of Babbage. There is no doubt that not only did Babbage know of many of these earlier works but many persons knew of them. These ideas and studies were not buried and forgotten but were written about in popular industrial books and magazines and taught to men of industry. Besides books previously quoted, books such as

38 Loc. cit.
The Operative Mechanic, Mathematics for Practical Men, and Géométrie et Méchanique des Arts et Métiers et des Beaux-arts reviewed and reported experiments and studies similar to those already mentioned. Popular industrial magazines such as The American Mechanics Magazine, Journal of the Franklin Institute, and The London Mechanics Magazine wrote about these studies. Furthermore, it is known that this and similar subjects were taught to workers, foremen, supervisors, plant superintendents, etc., in many schools.

46 Many of the articles in American Mechanics Magazine, etc., were from the London Mechanics Magazine or the London Mechanics Journal.
Subjects similar to those previously discussed led to even more specific studies of applications to industry. For example, studies were made as to how much force a person could exert for a short period of time using tools such as the following: draw-knife, auger, screw-driver (one hand), bench vice handle, chisel and awl (vertical pressure), pinchers and pliers, hand plane, hand or thumb vise, hand saw, stock bit, and small screw-drivers (twisting by the thumb and forefinger only).\(^{47}\)

Other specific studies such as the following were also made:

The handles of hammers are almost always made of nearly a uniform thickness in every part. Hence, the vibrations of the hammers are communicated to the hand of the workman, to whom they convey very unpleasant sensations—he is tired before he has exerted his strength. If the handle of the hammer, at a little distance from the upper end, or that nearest to the hammer, be made considerably smaller, for a short space, than in any other part, so as to spring a little, the alteration will be found a decisive improvement. Such a hammer will fall well, and diminish at the same time the workman's fatigue, convincing him also, that his blows are solid and effectual.\(^{48}\)

Other articles discussed such problems as "What is the reason why a screw nail is screwed home much easier with a long than with a short screw-driver, the handles in both cases being alike;\(^ {49}\) a subject quite similar to some in college textbooks of today.\(^ {50}\)

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\(^{47}\) *American Mechanics Magazine*, I, No. 20, June 18, 1825, p. 317.

\(^{48}\) *Journal of the Franklin Institute*, III, No. 5, May 1829, p. 284.


\(^{49}\) *American Mechanics Magazine*, I, No. 4, Feb. 26, 1825, p. 60; No. 5, March 5, 1825, p. 77; No. 8, March 26, 1825, pp. 122-123.

\(^{50}\) Barnes, op. cit., pp. 301 ff.
The previous portion of this chapter has been a sampling of studies of a fair day's work and allied subjects made prior to Babbage's *On the Economy of Machinery and Manufactures*. It has shown how widespread the studying and reporting was of a subject like a fair day's work. Although this has not been a complete analysis of previous works, it has shown that there was much study of industrial management problems prior to Babbage and that Babbage certainly used the works of others who preceded him. The following sections of this chapter further indicate the truthfulness of this.

**Industrial Education**

A great many people of England, France, Germany and the United States were studying and learning about industrial problems by the 1830's. This industrial education movement influenced Babbage's *On the Economy of Machinery and Manufactures*.

The beginnings of Industrial education go back at least as far as the sixteenth century. By the eighteenth century there was considerable activity in this area in both Germany and France. In 1747, France established its first engineering school, l'Ecole des Ponts et Chausses, under the very able direction of M. Jean-Rudolphe Anderson, S. F. "Beginnings in Industrial Education," p. 6, reprinted from *School and Society*, XIII, No. 331, April 30, 1921, pp. 518-523.

Perronet. With a man like Perronet as their director, this school undoubtedly taught subjects relevant to industrial management, for M. Perronet understood many industrial management problems. He made at least one excellent study of manufacturing. This study not only described the time for each operation, which Babbage tabulated and presented, but described the methods, materials, tools, and costs for each process. This study also entered into product costing by tabulating the probable costs and profits of each individual product.

Another work of Perronet consisted of studying the tasks of people and their pay. For this he invented an "odometer" which was described as follows:

Ce dernier instrument, qui peut s'adopter à toutes les machines en usage dans les travaux publics, sert à faire connaître le nombre de tours de manivelle exécutés par les ouvriers employés à ces machines, et à régler par ce moyen les tâches et les prix de leur travail; il est propre en outre à mesurer le chemin que l'on fait, soit à pied, soit en voiture, soit à cheval, ce qui le rendait utile aux armées,


53 See: "Division of Labor", Chapter VI.


Perronet's study was apparently done originally in 1738. Ref. Bourdel, op. cit., p. 323.
Perronet was also an expert on planning and foresight. 56

Industrial education continued to progress in France with the founding of the Conservatoire des Arts et Métiers 57 and the Ecole Polytechnique 58 at Paris in the 1790’s. This latter school not only provided teachers for many later industrial schools 59 but may have covered many important management concepts, for they did study such things as the amount of work a man could do in a day. 60

56 Bourdel, op. cit., p. 323.

Other works of this time which should be mentioned for their potential source material are the Descriptions des Arts et Métiers and Diderot’s Encyclopédie. These two works contain excellent descriptions of French industry and had significant influences on many later writings about industry. Ref. Watts, George B. "The Encyclopédie and the Descriptions des Arts et Métiers." The French Review, XXV, No. 6, May, 1952, pp. 444-454.


also conducted courses on public works and mining and may have provided Babbage with his example of a mining organization.

In Germany with the stimulus of the French developments, a commission was established in 1795 to study the German educational system. They concluded,

...that the Polytechnique school has for its chief object the education of directors, and persons to be employed in the management of public works. These persons must however receive such an education, as will give them an intimate acquaintance with the actual state of every great work that has been undertaken; with the reasons for conducting it in the manner followed, and the advantages or defects of the course pursued; they must also be able to judge properly of every new invention, and to enter into its merits, as well as to decide what steps must be taken to secure its adoption, and they must especially be rendered able to draw up accurate estimates of the probable cost of all new undertakings, and of the advantages likely to result from them.

For the reasons given above, it was in the first instance decided that the object of the Polytechnical school should be to educate men to be employed as Inspectors and Directors of Public Works, Agriculturists, Foresters, Miners, Founders, etc.; to contribute by the means of scientific instruction to improve the national manufactures, and other branches of industry.

Such a school was established in 1801 under the supervision of Francis Joseph Chevalier de Gerstner and became well received through


If one were to trace through the courses in mining at this or other French schools he might find much of the foundation for Henri Fayol's excellent work Administration Industrielle et Générale.

63 Gerstner, op. cit., p. 7.
the years by the public and numerous students. Of interest to this study is the fact that the able son of Francis Joseph Chevalier de Gerstner apparently knew both Olinthus Gregory and Charles Babbage and they both thus may have learned of work done in Germany.

In Scotland Professor John Anderson did work at Glasgow in the late eighteenth century which influenced industrial education. Before his death, in 1796, Professor Anderson "had for a period of thirty years, while Professor of Natural Philosophy in the university of that city, opened a class to which manufacturers and others had access, for the purpose of becoming acquainted with the fundamental principles of experimental physics." These classes were "regularly and numerous attended by a great many manufacturers and others engaged in operative occupations."

As a result of Professor Anderson's will, which "especially provided for the formation of a class of manufactures and artificers,"

64 Loc. cit.
65 Ibid., p. 10.
67 Ibid. p. 122. This was at the University of Glasgow, the same university where Adam Smith was teaching. Ref. Mitchell, Wesley C. Lecture Notes on Types of Economic Theory. New York: Augustus M. Kelley, 1949, pp. 66 ff.
68 Claxton, op. cit., p. 123.
69 Ibid., p. 122.
Anderson's University of Glasgow was established. There Dr. Garnett and then Dr. Birckbeck conducted lectures for manufacturers. Dr. Ure next became the lecturer and served for many years until, in consequence of some differences which had arisen between Dr. Ure and the students who attended the class, many students left the Anderson's University and founded the Mechanics Institution of Glasgow, in about 1823.70

The above developments, and other favorable conditions, led to the founding of many Mechanics Institutions throughout England. Dr. Birckbeck, who was formerly at Anderson's University, became one of the leaders in this movement and exerted a great deal of influence on it.71 "Within a few years after this period, there was hardly a city of any note in the Kingdom which had not institutions of a kindred description."72 The great growth of Mechanics' Institutions occurred in England in the late 1820's, and by 1850 there were recorded "610 Institutions with 102,050 subscribing members,...possessing 691,500 volumes in their libraries."73

The objective of most of these institutions was similar to that stated below:

70 Ibid., pp. 123-125.
71 Ibid., pp. 104 ff.
72 Claxton, op. cit., p. 125.
73 Hudson, op. cit., pp. vi ff.
This society was formed for the purpose of enabling Mechanics and Artizans of whatever trade they may be, to become acquainted with such branches of science as are of practical application in the exercise of that trade, that they may possess a more thorough knowledge of their business, acquire a greater degree of skill in the practice of it, and be qualified to make improvements and even new inventions in the Arts which they respectively profess. It is not intended to teach the trade of the Machine Maker, the Dyer, the Carpenter, the Mason, or any other practical business, but there is no Art which does not depend, more or less on scientific principles, and to search what these are, and to point out their practical application, will form the chief object of the Institution.4

As noted above, many of these Mechanics' Institutions were interested in the practical applications of scientific principles to industry. The means chosen to educate the members of these Institutions were usually lectures, classes, libraries, and experimental workshops and laboratories.5 Some, to further their objective, supported or encouraged the publication of industrial magazines.6 These magazines became quite popular in the 1820's and carried many items of interest to the student of industry.7

74 Hudson, op. cit., p. 56 [Underline added]
75 Ibid., pp. 54 ff.
Claxton, op. cit., pp. 81 ff.
Hudson, op. cit., p. 217.
77 Rezmeck, op. cit., pp. 808 ff.

There were many, many other facets to this industrial education movement, before and after the time of Babbage—too many to be covered here. For this study the following points are important.

First, Babbage did not stand alone in his search for principles applicable to manufacturing. There were hundreds and thousands who were actively interested in knowing and studying the application of scientific principles to industry.78

Second, this movement, with its numerous people interested in machinery and manufacturing undoubtedly provided a market which helped Babbage's book, On the Economy of Machinery and Manufacturers, achieve immediate success and acceptance.

Third, this movement probably not only indicated to Babbage the potential market for such a book but undoubtedly influenced the book's contents. Some of Babbage's many illustrations in On the Economy of Machinery and Manufacturers, certainly must have come from industrial magazines of the time because there is too high a degree of similarity

78 Hudson, op. cit., pp. v ff.

Dupin, Géométrie, op. cit., III, preceding Chapter I.


for the likeness to be accidental. To Babbage's credit it should be mentioned that he did not claim originality for his work as indicated by the following statement he made under the topic of copying: "The mysteries, however, of an author's copying, form no part of our inquiry, although it may be fairly remarked, that, in numerous instances, the mental far eclipses the mechanical copyist."  

Fourth, at least one of the courses developed in this industrial education movement must have had a significant influence on the contents of Babbage's book, as indicated in the discussion of Baron Dupin's work which follows as the next topic in this chapter.

Fifth, some of the topics in this industrial education movement were of definite interest and applicability to industrial management. As indicated in the earlier discussion of a fair day's work and the following discussion of Dupin's work.

79 Articles such as the following were found in the American Mechanics Magazine which were similar to Babbage's illustrations. (This magazine frequently republished articles from the London magazine and these articles probably appeared there.)


A thorough search might find that most of Babbage's illustrations came from similar articles. This search was not made for this study due to the difficulty of obtaining the necessary numerous volumes of these magazines.

80 Babbage, C., Economy, op. cit., p. 113.
Baron Dupin

For many years Baron Charles Dupin of France studied industry and commerce and encouraged the improvement of French industry. After observing the growing success of the industrial education movement in Scotland and England, he established a similar program at the Conservatoire des Arts et Métiers, at Paris, in 1824. This program spread rapidly throughout France with similar courses being instituted in 59 cities in 1825, and 98 cities in 1826. Teachers for this movement were largely drawn from former pupils of l' Ecole Polytechnique. The students were "Artistes et des Ouvriers, des Sous-Chefs et des Chefs d'ateliers et de manufactures," of whom over 5000 attended the courses by the end of 1826.

Fortunately for the history of management concepts, Dupin's lectures on Géométrie et Mécanique des Arts et Métiers were published. Some of these forty-five lessons contain material relating to...
to industrial management. Unfortunately for the history of management, the merits of this work have apparently not been recognized in modern time; but thousands of Frenchmen are recorded as having studied the material in the late 1820's.

These lectures of Dupin must have influenced Babbage's writing on the introductory essay in the Encyclopedia Metropolitana and the book, On the Economy of Machines and Manufacturers, for a comparison with the contents of portions of Dupin's lectures reveals so many points of similarity that the above conclusion becomes quite certain. The influence of Dupin on Babbage may have come about in some of the following ways.

Babbage undoubtedly knew of Dupin's work for it received wide recognition in England and other countries. Also, Babbage may have

85:cont.

The famous French economist, J. B. Say, was also connected with this work at the Conservatoire des Arts et Métiers for he was their Professor of Industrial Economy. Ref. Magazine "The Conservatory of Arts." American Mechanics Magazine, I, No. 22, July 2, 1825.

86 See Appendix.

87 Dupin, Géométrie, op. cit., III preceding Chapter I.

88 Birckbeck, op. cit., p. iv.


known Dupin personally or have observed his courses in operation, for Babbage knew many French notables and travelled in France in 1824, 1826, and 1827.\textsuperscript{89}

Dr. Birckbeck's translation of Volume I of Dupin's lectures may have influenced Babbage with the following introduction to the book: "Some minds of adequate qualification and powers, may at length be influenced to attempt an equally clear, and still more complete exposition of the application of Geometry to the Arts...."\textsuperscript{90} Perhaps Babbage accepted the challenge—he certainly accepted other challenges in his lifetime. Curiously, although the translation of Volume II of Dupin was announced as "preparing for publication" and Volume III promised, there is no evidence of either being published.\textsuperscript{91}

A further possible connection between Dupin and Babbage is indicated by the following advertisement which appeared in the front of John Herschel's, 1830, \textit{Preliminary Discourse on the Study of Natural Philosophy}:

\begin{quote}
At an early period will be published, \textit{A Preliminary Discourse on the Objects and Advantages of the Study of the Useful Arts}, by the Baron Charles Dupin, member of the Institute of France and the Chamber of Deputies.\textsuperscript{92}
\end{quote}

\textsuperscript{89} See Chapter III.

\textsuperscript{90} Birckbeck, \textit{op. cit.}, p. xv.

\textsuperscript{91} \textit{Ibid.}, p. preceding title page.

This advertised work is not known to have ever been published.

Possibly the French revolution of 1830 prevented Baron Dupin from publishing the above book and this gave Babbage the opportunity to step in and publish one 'like Herschel's'.

In order to provide an idea of the contents of Dupin's course, some sections which show similarities to Babbage's work and which contain some of Dupin's industrial management concepts have been translated and presented in the Appendix. This appendix is not intended to be complete or conclusive with respect to Dupin's work but only a preliminary analysis with hopes that further study of Dupin's contributions can be made at another time.

Below is a summary from the Appendix of some of the topics Dupin wrote about and taught in his courses.

Music and rhythm are important in doing work for they help to develop regularity, reduce fatigue, and even affect the emotions. In handling workers there are tones and ways of speaking and handling workers which a foreman or industrial head should use and others which he should not use.

Men can not use their full physical strength except for short periods of time. Coulomb, Bernoulli, Schulze, Buchanan and others have made important studies of this subject. Since it is important for the foreman to produce each job with a minimum outlay of money he should know how to produce each desired effect with a minimum of energy. For example, Coulomb found the men can produce the most work when walking up an incline or on level ground by maintaining a regularity of step and resting regularly as they feel the need. The best way for a man to raise a load is for him to climb without any load and then let his own descending weight lift the load. Coulomb also studied the spading of earth and found it a very costly way to employ the strength of man.

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93 See "Reasons for Writing the Economy of Machinery & Manufactures," Chapter III.
One of the most important considerations in using the strength of men, is the speed with which each man can execute the various types of movement. This applies also to the professions and artisans for they must learn to apply their intellectual faculties without loss of time. Furthermore attention should be paid to the best posture for doing various tasks for it often can be improved.

Much more attention should be paid to teaching the young people subjects such as reading, writing, and mathematics and sciences that they will need in their work. More attention should also be given to the nourishment workers receive, and to community chests for workers to meet emergencies. It is important that both the class of managers and the class of workers understand how to improve their well-being.

It is important for both the worker and manufacturers that proper tools are available for each job. France is not nearly as good in this respect as England. They also need to learn more concentration and improve their skills in using tools. They need to study the strength and speed necessary to apply to each portion of the body to do each type of work, for much improvement can be made over the present routines. Also the proper speed for each mechanical operation should be ascertained.

As greater amounts of capital are employed the improvement of the speed of each operation becomes more important and the division of labor can be increased with the movements for each worker becoming simpler, easier, more rapid, and more perfect. Pin making is an example of this. It is a precious art in foremen and manufacturers to know how to break a job into its simplest elements, and nevertheless keep them as small a number as possible, to assign each part to expert workers. In larger establishments more attention can be paid to obtaining the proper proportion and duration of each operation.

As industry progresses more machines are used and more intelligent workmen are needed and thus we must pay attention not only to develop proper movements of workers' bodies but also improve their senses and intelligence. This will become increasingly necessary as industry advances at a more and more rapid pace.

Those were ideas expressed by Baron Dupin. Can anyone who reads them or studies his work in the Appendix believe that Babbage was the only one writing about management problems at the time he wrote his
On the Economy of Machines and Manufactures? Also, can anyone who has studied the preceding material of this chapter still believe the classical interpretations of management history which profess that the foundations of management were laid at the end of the nineteenth century with no significant work being done prior to that date?

Other people and circumstances which influenced Babbage

Many of the people and circumstances which influenced Babbage's life and works have been indicated in the preceding portions of this chapter and in Chapters II-IV. It is not intended that all such influence should be covered, but there are several others which should be noted.

Dr. William Hyde Wollaston may have influenced Babbage's life and works for he was a friend and advisor of Babbage. Dr. Wollaston was a leading British scientist and interested in manufacturing. He was one of the ablest and most renowned of the English chemists and natural philosophers and celebrated for the minuteness of his experiments and his mechanical ingenuity. His quickness and keenness of observation plus his ever searching of new ideas made him a favorite of many. Each year he "spent some time travelling about England and abroad, generally with one or more companions. His chief interest was in seeing manufactures..." The extent to which Dr. Wollaston

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94 Babbage, Charles Passages from the Life of a Philosopher. London: Longman, Green, Roberts & Green, 1864, p. 42. etc.

influenced Babbage's ideas on science or industry is not known, but there was undoubtedly some for the two were friends from Babbage's days at Cambridge until Dr. Wollaston's death in 1828.96

William Herschel may also have influenced Babbage, for Babbage was a favorite of his and a very close friend of his only son, John Herschel.97 As the world's most outstanding telescope maker William Herschel was a superb craftsman and a student of machinery and manufacturing. James Watt, of steam engine fame, was one of the manufacturers with whom William Herschel became well acquainted.98

95 cont.

Hasted, Henry Reminiscences of a Friend, 184-?

"Life of Wollaston." Littel's Living Age, XI, October, 1846, pp. 9-22.

96 Hasted, op. cit., pp. 1 ff.

97 See "University of Cambridge," Chapter II and other topics in Chapters II-IV.

For works on William and John Herschel see:


As the leading astronomer of his day, William Herschel knew many English and foreign scientists and undoubtedly helped Babbage become accepted in scientific circles.

Besides possibly learning about tools, machinery, and manufacturing from William Herschel, Babbage may have learned other things for the following similarities between the two were noted: recording of observational data, ability to interpret observed data, use of imagination, and a search for knowledge. William Herschel said, "I yet determined with a sort of enthusiasm to devote every moment I could spare to the pursuit of knowledge..." Babbage similarly wrote, "every moment of my working hours has always been occupied by some train of inquiry." Again, it is difficult to say the extent to which Babbage became influenced by William Herschel but their close association certainly must have been beneficial to Babbage.

John Herschel probably had more continued influence on Babbage than any other person. It was probably as students at Cambridge that these two became close friends. From then on Babbage seemed to be frequently trying to follow in Herschel's footsteps and receiving aid from him. At Cambridge and after, Herschel always received

99 Ibid., p. 190.

100 Ibid., p. 19.


102 See "University of Cambridge," Chapter II.
high honors and was continually recognized for his work. A few of John Herschel's recognitions were as follows: senior wrangler, member of the Royal Society at an early age, recipient of the Copley Medal, secretary of Royal Society, welcomed by all foreign scientists, knighted, made a Baronet, Master of the Mint, and many other honors. Babbage frequently tried to achieve similar honors but usually fell short of his goal. Amid the animosities and feuds which troubled the lives and impaired the usefulness of many of the mathematicians of the earlier part of the nineteenth century, Herschel succeeded in retaining the love of all. Babbage continued to engender enemies throughout his life.

Many of the effects of John Herschel on Babbage were also noted in Chapters II - IV, including the probable effect of Herschel's Preliminary Discourse on Natural Philosophy on Babbage's On the Economy of Machinery and Manufactures.

The circumstances which influenced Babbage's life and work include the reform movement of the first half of the nineteenth century. The 1820's in England were years of growing agitation for improvement

103 See footnote 9.

104 See Chapters II-IV.


106 See "Reasons for Writing On the Economy of Machinery and Manufactures" Chapter III.
in many areas, especially in the government but also in areas such as manufacturing, education, science, etc. Babbage certainly was influenced by this reform era and was himself an influence on it. 107

By 1832 the political reform movement in England became so active that property was destroyed, the Duke of Wellington stoned, and the king openly jeered in the streets. Finally in June, 1832 the opposition of the House of Lords was overcome and the Reform Bill allowed to pass giving more parliamentary representation. Thus England achieved by parliamentary means what was requiring revolutions in other countries.

This reform movement had various effects on Babbage. First, Babbage had been one of the leaders for mathematical reform and had succeeded in helping to introduce modern calculus into England. 108 Second, he was one of the very active leaders for scientific reform. 109 Third, as Lucasian Professor he was advocating educational reforms. 110


McCarthy, Justin The Epoch of Reform 1830-1850. New York: Charles Scribner's Sons.

Mitchell, op. cit., pp. 61 ff.


108 See "Introduction of Modern Calculus into England," Chapter II.

109 See "Decline of Science," Chapter III.

110 Loc. cit.
Fourth, politically Babbage backed reform candidates and became one himself, in 1832.\footnote{111} Fifth, the political turmoil led to frequent changes of government and hindered Babbage's receiving full government support for his calculating machines.\footnote{112} Sixth, the interest in industry, which grew with this reform movement, helped the sale of Babbage's \textit{On the Economy of Machines and Manufactures}.\footnote{113}

Another circumstance which influenced Babbage's writings on manufacturing was the general framework around which the \textit{Encyclopedia Metropolitana} was built. This framework was established by T. S. Coleridge under the supervision of Rev. Thomas Curtes and Olinthus G. Gregory.\footnote{114} This encyclopedia was started in 1818 but not completed until 1845 and, as was the custom, when various portions of the work were finished they were issued as separately bound treatises.\footnote{115}

Coleridge's "Preliminary Treatise on Method" introduced this new encyclopedia and explained "...that there is a Science of Method; and that that Science, like all others, must necessarily have its Principles."\footnote{116} To carry out these ideas in the \textit{Encyclopedia Metropolitana}...

\footnote{111} See "Entry into Politics" and "Candidate for Parliament from Fensbury." Chapter III.
\footnote{112} See Chapters II and III.
\footnote{115} Loc. cit.
\footnote{116} Ibid., p. 3.
Metropolitana "the principles of Unity and Compression", instead of "those of variety and extent" were followed. The objective was to build upon what is essential that which is obviously useful, and upon both whatever is elegant or agreeable in Science..."

Following the above ideas the Encyclopedia Metropolitana consisted of two volumes on the pure sciences, followed by six volumes of mixed and applied science, and concluded with biographical and miscellaneous volumes. The plan of the entire encyclopedia was thus based on Coleridge's "Preliminary Treatise on Method". Each individual volume was then frequently based on a similar introductory essay covering essential general principles on which later practical details of that volume could be built. It was thus appropriate that Babbage's "Introductory View of the Principles of Manufactures", which served as an introduction to the volume on machinery and manufacturing, should "endeavor to state the principles on which their success depends, and to trace both the causes and the consequences of the application of machinery to supersede the skill and power of the human arm."

117 Ibid., p. 54.
118 Loc. cit.
119 Ibid., pp. 52 ff.
121 Ibid., p. 3.
Beside the general plan of the *Metropolitana* there was another factor which probably accounted for some of the contents chosen by Babbage's introductory essay. Joseph Low, in his section of *Encyclopedia Metropolitana* on Commerce, was to approach his subject from the following points of view: historically, present conditions, and progress of various specific industries. Nassau Senior in his section on Political Economy was to cover the traditional approach of wealth, value, population, distribution of wealth, etc. Thus, these two more common approaches to what might have been said about manufacturing were to be covered elsewhere in the encyclopedia. Otherwise, Babbage might have included more of those approaches in his introductory essay.

These were some of the people and circumstances which influenced Babbage and his industrial management concepts. There are certainly others such as the economists Richard Jones, T. R. Malthus, and Nassau Senior whom Babbage knew well. Much might be learned by comparing Babbage's writings to other works such as those of the above men. This was not done, however, since this is not an economic dissertation and due to the fact that the background material is endless. Sufficient information has, however, been presented to show that there was much study of industrial management concepts prior to Babbage and that Babbage was truly a product of his time.

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Chapter Summary

Babbage's works have been characterized as being far in advance of their time and the first to study industrial organization from the scientific standpoint. A study of the people and circumstances which influenced Babbage's works revealed, however, that he was an integral part of his time. Contrary to the classical interpretations of management history, a great many significant studies of industrial management problems were made prior to the time of Babbage. So many, in fact, that it became necessary to present in this chapter only a sampling of Babbage's predecessors. This chapter makes no pretense to cover all the areas of mechanics, economics, statistics, the physical sciences, House of Commons Committee Reports, and other areas from which Babbage drew his ideas.

In the concept of a fair's day work there were many men such as the following who preceded Babbage: Dé la Hire, Bernoulli, Desaguliers, Coulomb, Robinson, Buchanan, Gerstner, Welcher, Nordwall, Vauban, Christian, Nicholson, Emerson, Leslie, Hachette, Morisot, Hassenfratz, Navier, Amontons, Bouguer, Euler, Schulze, Sauveur, Belidor, and others. Not only did these men study and experiment on how much work men could be expected to do in a day but many of them intended their results to be useful to industry.

Charles August Coulomb made the most famous and most frequently quoted observations. These were first published in 1781 and then re-published in 1890 and 1921, all in French. If this work had been translated into English, the famous pig iron and shoveling experiments
of F. W. Taylor might not have received the undue recognition they have and Taylor’s claim to great originality might have been unmasked long ago.

The following are some of the things that Coulomb wrote about:
how to combine the different degrees of force, speed, and time, so that a man can furnish the greatest amount of work with the least fatigue; different combinations of force, speed, and time needed for different jobs such as the following: men climbing a ramp or stairway during a work day, with or without a weight; working on a horizontal plane; working with wheelbarrows; pile driving; using levers; and concerning the quantity of action which men consume in their daily work when they work the earth with a spade. One of Coulomb’s conclusions was that for the best use of a man’s physical force his action should be cut by periods of rest. He also gave cautions in making observation.

These works of Coulomb are known to have influenced Babbage’s works and undoubtedly influenced the work of others to follow.

Another of those who studied a fair day’s work was M. Schulze, who made statistical studies of the works of 20 different men. M. Christian, who also studied this same subject, made comments on such subjects as: the first economic rule for the use of the force of the man consists in dispensing it in a period of time and long enough to permit frequent intervals of rest; factors which caused variation in a man’s output; and types of movements which men can
quickly produce. Excerpts from Francis Gerstner were also given on this subject.

The above and other experiments received a great deal of attention at the time of Babbage because they were quoted in books, popular industrial magazines, and taught in many schools to workers, foremen, supervisors, etc. These studies also led to other studies on the force required for the use of specific tools, proper design of tools to reduce fatigue, proper use of the screwdriver, etc.

Although this was not a complete analysis of all previous works, it showed that there was much study of industrial management problems prior to Babbage, and that Babbage certainly used the works of others who preceded him when he wrote *On the Economy of Machinery and Manufactures*.

The industrial education movement also influenced Babbage. The beginnings of this movement go back as early as the sixteenth century and by the eighteenth century there was much activity in both Germany and France. Some of the schools active in this area were: the Ecole des Ponts et Chausses, with M. Perronet as director; Conservatoire des Arts et Metiers; and Ecole Polytechnique. In Scotland and England the work of Professor John Anderson followed by that of Dr. Birckbeck led to the establishment of popular industrial classes and then, in the 1820’s, to many Mechanics’ Institutions. This industrial education movement spread rapidly throughout England in the 1820’s and by 1850 there were at least 610 of these mechanics’ institutions with over 100,000 members. The objective of many of these institutions was to
study the practical application of scientific principles to industry.

This entire movement had many, many ramifications, but for Babbage it meant the following: he did not stand alone in his search for principles applicable to manufacturing, it provided a market for his book on machinery and manufacturing, and it influenced the contents of this book.

Fortunately for the history of management the material taught in France to men of industry was recorded. This course undoubtedly had some influence on Babbage’s book as indicated. Some of the topics covered by Baron Dupin in this course are as follows: rhythm; the importance of the foreman knowing how to produce each job with the minimum outlay of money and energy, similarly true for intellectual faculties; importance of posture; improving the well-being of the working class; proper tools; and future of manufacturing. (See Appendix)

Continuing with some of the other people and circumstances which influenced Babbage, there were leading scientists such as the following who affected Babbage’s career and works: Dr. Wollaston, William Herschel, and John Herschel. Other circumstances which influenced Babbage were the reform movement, and the general framework around which the *Encyclopedia Metropolitana* was built. There were undoubtedly an almost unlimited number of people and circumstances which influenced Babbage, but enough have been sampled to indicate that there was much study of industrial management concepts prior to Babbage and to show that Babbage was truly a product of his time.
CHAPTER IX

INFLUENCE AND SIGNIFICANCE
OF CHARLES BABBAGE

Introduction

The preceding chapter presented people and circumstances which affected Babbage's industrial management writings. The present chapter studies whether or not Babbage influenced others and evaluates his significance in the historical development of industrial management concepts.

Some of Babbage's work certainly left lasting impressions; such as, the introduction of modern calculus into England, designing of calculating machines, and co-founding various scientific societies.¹ But what about the area of industrial management? That is the point of concentration for this chapter.

Misconceptions of nineteenth century industrial management

In the preceding chapter it was noted that contrary to the teachings of management historians a considerable amount of work had actually been done on industrial management concepts prior to Babbage. To properly understand the influences which Charles Babbage had on others, one must similarly realize that there were many, many developments after Babbage and prior to Fredrick W. Taylor which have not been

¹ See Chapters II-IV.
accurately recorded by management historians.

This chapter, in analyzing the influences of Charles Babbage, indicates how the work which had been done prior to Babbage did not suddenly stop with Babbage's *On the Economy of Machinery and Manufactures*, but continued throughout the nineteenth century. The foundations of industrial management were not laid at the end of the nineteenth century but long before that. The work which was supposed to have started the scientific management movement was actually based much more on previous works than has been adequately recognized.

Unfortunately, it was too great an undertaking for this dissertation to study all the industrial management thinking and writing after Babbage or to even attempt to cover all Babbage's influences on later developments. The research for this chapter was limited to determining whether or not "Babbage's work produced little subsequent impression," and to areas which might contribute most to a better understanding of management history. It is hoped that the information presented will indicate to others the need for much more research on the true history of management.

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C. B. Thompson gave a similar impression when he wrote, "it does not appear that the modern group of scientific managers are in the slightest degree indebted to Babbage's work..." Ref. Thompson, C. Bertrand *"The Literature of Scientific Management."* Quarterly Journal of Economics, reprinted in Thompson, C. Bertrand. Cambridge: Harvard University Press, p. 6.
John Stuart Mill was one popular author who helped perpetuate Babbage's name and ideas. Although the personal relationship between these two men is not known, it would be surprising if they were not at least acquainted for, as noted in earlier chapters, Babbage had a very wide range of acquaintances and so, undoubtedly, did know John Stuart Mill.

This study made no research of possible influences of these two on each other but the following direct references to Babbage were noted in Mill's *Principles of Political Economy*.

The manner in which these [invention and use of tools and machinery] serve to increase production and to economize labour, needs not be specially detailed in a work like the present: it will be found explained and exemplified, in a manner at once scientific and popular, in Mr. Babbage's well-known *Economy of Machinery and Manufactures*.5

Mill also notes Babbage's examples of how fraud or trustworthiness can hinder or help trade relationships.6 He further noted Babbage on the division of labor and quoted the following passage:

> 'When the human hand, or the human head, has been for some time occupied in any kind of work, it cannot instantly change its employment with full effect. The muscles of the limbs employed have acquired a flexibility during their exertion, and those not in action a stiffness during rest, which renders every change slow and unequal in the commencement. Long habit also produces in the muscles exercised a capacity for enduring

4 See Chapters I-IV.


6 Ibid., p. 112.
fatigue to a much greater degree than they could support under other circumstances. A similar result seems to take place in any change of mental exertion; the attention bestowed on the new subject not being so perfect at first as it becomes after some exercise. The employment of different tools in the successive processes is another cause of the loss of time in changing from one operation to another. If these tools are simple and the change is not frequent, the loss of time is not considerable; but in many processes of the arts, the tools are of great delicacy, requiring accurate adjustment every time they are used; and in many cases, the time employed in adjusting bears a large proportion to that employed in using the tool. The sliding rest, the dividing and the drilling engine are of this kind: and hence, in manufactories of sufficient extent, it is found to be good economy to keep one machine constantly employed in one kind of work: one lathe, for example, having a screw motion to its sliding-rest along the whole length of its bed, is kept constantly making cylinders, another, having a motion for equalizing the velocity of the work at the point at which it passes the tool, is kept for facing surfaces; whilst a third is constantly employed in cutting wheels, 7

The above quoted passage is important for it helped to perpetuate ideas which Babbage had expressed on this subject. However, as noted in the previous chapter, these ideas were not original with Babbage; these are also the sort of ideas which too frequently have been pictured as not originating until the end of the nineteenth century. With the wide circulation which this book of Mill’s had, these ideas certainly received considerable publicity throughout the last half of the nineteenth century.

In connection with the above quotation, it is interesting to note that Mill pointed out the resting effect which is sometimes present in rotating from one job to another or from bodily labor to mental labor and vice versa. 8

7 Ibid., pp. 126-127.
8 Ibid., p. 127.
Other citations which Mill gave to Babbage included an explanation and illustration of how one can achieve "more economical distribution of labour, by classing the workpeople according to their capacity." A further lengthy quote from Babbage dealt with the problems of organization and operation which occur as a factory expands its activities. Mill also seemed to have been impressed by Babbage's discussion of profit sharing and noted that "Mr. Babbage has the great merit of having pointed out the practicability, and the advantage, of extending the principle of manufacturing industry generally."

Throughout many editions of his Principles Mill continued to recognize the merits of profit sharing and Babbage's writings on it, but with the third edition he dropped a lengthy quote from Babbage on the subject.

The preceding was not intended to be a complete analysis of Babbage's influence on John Stuart Mill. Although such a study might be useful to the economists, only enough was presented here to indicate that Mill certainly saw merit in some of the ideas expressed in Babbage's On the Economy of Machinery and Manufactures. The great popularity of Mill's work certainly helped continue the influence of Babbage.

9 Ibid., p. 129.
10 Ibid., pp. 132-133.
11 Ibid., pp. 765-766.
12 Ibid., p. 766-767. Note that Mill refers to a source from which Babbage might have obtained ideas on profit sharing. This Report of the Children's Employment Commission was not located in this research. Ref. Ibid., p. 765.
W. Stanley Jevons

Jevons was another who helped perpetuate Babbage's name and ideas. Even though Jevons was of a younger generation than Babbage, these two men were at least personally acquainted for they were both active in the London Statistical Society. Babbage may have influenced some of Jevons' ideas for they both had interests such as the following in common: calculating or analytical machinery, bank statistics, graphing of statistics, economic concepts, analysis of human thought process, etc. For this study, however, the references which Jevons


Ibid., XXXIV, 1871, pp. 111 ff.


17 Babbage, Charles Economy, op. cit.

Jevons, Principles of Political Economy, op. cit.

writings made to Babbage were most important.

In the Principles of Science, A Treatise on Logic and Scientific Method, Jevons made the following references to Babbage: the calculating machine;\textsuperscript{19} lighthouse signals;\textsuperscript{20} the formation of a collection of the constant numbers of nature, a work which has at last been taken in hand by the Smithsonian Institution;\textsuperscript{21} system used in producing the French mathematical tables, quoted in Economy of Manufactures;\textsuperscript{22} distinction between universal principles and general principles, from The Exposition of 1851;\textsuperscript{23} and "that most profound and eloquent work, The Ninth Bridgewater Treatise."\textsuperscript{24}

In The Theory of Political Economy Jevons referred to Babbage as follows:

The most favorable load for a porter was investigated by Coulomb, and he found that most could be done by a man walking upstairs without any load, and then raising his burden by a means of his weight in descending. A man could thus raise four times as much in a day as by carrying bags on his back with a most

\textsuperscript{18} cont.

Jevons wrote various books on logic; such as, Jevons, W. Stanley Elementary Lessons In Logic: Deductive and Inductive. London: Macmillan and Co., 1878.


\textsuperscript{20} Ibid., p. 194.

\textsuperscript{21} Ibid., p. 329.

\textsuperscript{22} Ibid., p. 403.

\textsuperscript{23} Ibid., p. 646.

\textsuperscript{24} Ibid., p. 743.
favorable load. This great difference doubtless arises from the
muscles being perfectly adopted to raising the human body, whereas any additional weight throws irregular or undue stress upon
them. Charles Babbage, also, in his admirable 'Economy of
Manufactures,' has remarked on this subject, and has pointed out
that the weight of some limb of the body is an element in all
calculations of human labor.

'The fatigue produced on the muscles of the human frame,'
says Babbage, 'does not altogether depend on the actual force
employed in each effort, but partly on the frequency with which
it is exerted. The exertion necessary to accomplish every opera-
tion consists of two parts: one of these is the expenditure of
force which is necessary to drive the tool or instrument; and the
other is the effort required for the motion of some limb of the
animal producing the action. In driving a nail into a piece of
wood, one of these is lifting the hammer, and propelling its head
against the nail; the other is raising the arm itself, and moving
it in order to use the hammer. If the weight of the hammer is
considerable, the former part will cause the greatest portion of
the exertion. If the hammer is light, the exertion of raising
the arm will produce the greatest part of the fatigue. It does
therefore happen, that operations requiring very trifling force,
if frequently repeated will tire more effectually than more
laborious work. There is also a degree of rapidity beyond which
the action of the muscles cannot be pressed.'

Jevons concluded the above idea "was a subject admitting of inter-
esting inquiry, and....tried to determine, by several series of experi-
ments, the relation between the amount of work done by certain muscles
and the rate of fatigue."  

Just preceding the above quotations, Jevons had several paragraphs
which are not credited to Babbage but which ideas probably came prim-
arily from Babbage. These two paragraphs are quoted below due to their

25 Jevons, W. Stanley The Theory of Political Economy. London:

26 Ibid., p. 224.
relation to later management developments, especially the science of shoveling.

Let us take such a simple kind of work as digging. A spade may be made of any size, and if the same number of strokes be made in the hour, the requisite exertion will vary nearly as the cube of the length of the blade. If the spade be small, the fatigue will be slight, but the work done will also be slight. A very large spade, on the other hand, will do a great quantity of work at each stroke, but the fatigue will be so great that the labourer cannot long continue at this work. Accordingly, a certain medium-sized spade is adopted, which does not overtax a labourer and prevent him doing a full day's work, but enables him to accomplish as much as possible. The size of a spade should depend partly upon the tenacity and weight of the material, and partly upon the strength of the labourer. It may be observed that, in excavating stiff clay, navvies use a small strong spade; for ordinary garden purposes a larger spade is employed; for shovelling loose sand or coals a broad capacious shovel is used; and a still larger instrument is employed for removing corn, malt, or any loose light powder.

In most cases of muscular exertion the weight of the body or of some limb is of great importance. If a man be employed to carry a single letter, he really moves a weight of say a hundred and sixty pounds for the purpose of conveying a letter weighing perhaps half an ounce. There will be no appreciable increase of labour if he carries twenty letters, so that his efficiency will be multiplied twenty times. A hundred letters would probably prove a slight burden, but there would still be a vast gain in the work done. It is obvious, however, that we might go on loading a postman with letters until the fatigue became excessive; the maximum useful result would be obtained with the largest load which does not severely fatigue the man, and trial soon decides the weight with considerable accuracy.27

As noted later, Jevons¹ work was known by both Frank Gilbreth and F. W. Taylor and might have helped provide a connecting link between Babbage and later developments.28 This is certain, however, Jevon's

27 Ibid., pp. 221-223.

works were widely read. His notices of Babbage's work also did not permit Babbage's name to die out in connection with the "Economy of Manufactures." Who knows how many persons were influenced by Jevons' references to Babbage?

**Alfred Marshall**

Alfred Marshall was a third economist who helped perpetuate ideas expressed by Babbage and one whose own ideas might have been influenced by Babbage. For example, one wonders if the following passage of Babbage might not have had some effect on Marshall's concepts of marginalism for it had the rudiments of the idea and Marshall frequently quoted it:

...the master manufacturer by dividing the work to be executed into different processes, each requiring different degrees of skill or force, can purchase exactly that precise quantity of both which is necessary for each process; whereas if the whole work were executed by one workman that person must possess sufficient skill to perform the most difficult and sufficient strength to execute the most laborious of the operations into which the work is divided.29

Although Marshall made only one other direct reference to Babbage in his Principles of Economics30 it is very possible that there were

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30 Marshall, Principles, op. cit., p. 278.
other areas of influence, for many of the ideas expressed by Marshall on machinery were similar to Babbage's.31

For this study it is interesting to note that in his Industry and Trade Marshall called attention to the similarity between the works of Babbage and Taylor, such as in "the common task of shoveling the earth."32 Unfortunately, Marshall too believed that Taylor's ideas were "thought out anew" and thus helped perpetuate the misconception of Taylor's originality.33 In this same book Marshall also recognized the similarity between Babbage's work and Lardner's Railway Economy.34 There is no doubt that Marshall had read Babbage carefully. A thorough analysis might reveal that Babbage had more influence on Marshall's writings than has been previously recognized. Marshall at least was another who helped call attention to Babbage's work.

Multiplicity of possible influences of Babbage

The previous sections have shown that some of Babbage's concepts were favorably perpetuated by such leading economists of the nineteenth century as Mill, Jevons, and Marshall. Considering the number of other economic writers there were in the nineteenth century, there could have been many who continued the ideas expressed by Babbage.35

31 Ibid., p. 866. (See topics indexed under machinery)
33 Ibid.
34 Ibid., p. 449.
35 Karl Marx was one of those who might have been influenced by Babbage. Ref. Marx, Karl The Poverty of Philosophy. London: Martin Lawrence, Ltd., n.d., p. 117.
Besides these, there were many more channels of thought which could have continued ideas Babbage expressed or could have been influenced by Babbage. A few of these were: mechanics' institutions, industrial magazines, writings on labor, studies of natural philosophy, civil engineering, mechanical engineering, railway writings, industrial education, industrial practices, etc. Thus there were a multiplicity of possibilities where Babbage's influence might have been felt.

Instead of examining each of the above possible channels of Babbage's influence it was decided to limit the research by jumping to later developments and determining whether or not Babbage influenced those who were supposed to have started the study of industrial management. If Babbage influenced some of the leaders of the scientific management movement then certainly the statement, "Babbage's work produced little subsequent impression," would be proved false. To analyze the possible influence of Babbage, the works of F. W. Taylor and Frank Gilbreth were selected because they were two of the leaders in the scientific management movement and because information was available on them in two libraries.

Fredrick W. Taylor

Since management historians have given so much credit to the scientific management movement and to F. W. Taylor as "the father of

36 Urwick, op. cit., p. 28.

scientific management," one question of interest to this study was, did Babbage influence Taylor?

In order to answer this question adequately it was necessary to make some analysis of Taylor's work and possible sources of his ideas. Unfortunately for management history research, many of Taylor's papers and books were destroyed after the death of Mrs. Taylor and thus many papers and books which might have provided information on the primary sources of Taylor's ideas are forever unavailable. However, there still was sufficient information left in the Fredrick Winslow Taylor Collection at the Stevens Institute of Technology and other sources to provide information for an appraisal of Taylor's work.

The common impression given by Taylor's writings and by most management historians has been, "There is no plagiarism in Taylor....His ideas were his own, wrung by sheer force of personal effort, energy and originality from the unsympathetic environment of the machine-shops of the United States."39

37 cont.


38 This information was learned while at the Taylor Collection at Stevens Institute of Technology and from some who had known the Taylor library in its earlier days.

39 Urwick, op. cit., p. 28.
An analysis of Taylor's work and possible source of his ideas revealed that the previous impression is completely and totally false. This study found that there was a great deal of plagiarism and misrepresentation in Taylor's works. Instead of being highly original, Taylor actually sought and accepted credit for much that others had done previously.

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40 See Chapter I for documentation on previous impressions.

Taylor once commented, "Hardly a single piece of original work was done by us in Scientific Management," but this is entirely contrary to the impressions given by most of Taylor's writings. Ref. for quote: Dartmouth College Address and Discussions at the Conference on Scientific Management. Hanover, New Hampshire: Amos Tuck School of Administration and Finance, 1912, p. 48.


For an example of misrepresentation compare Taylor's story of his rise in Midvale Steel with the actual "inside track" which he had. Ref. Taylor, Fredrick W. Principles of Scientific Management, p. 48 in Person, op. cit. Also: Copley, Frank Barkley Fredrick W. Taylor. New York: Harper and Brothers, 1923, I, pp. 61, 107, 117.

42 When some of the similarities between Taylor's work and earlier works were pointed out to Taylor in the latter part of his life he professed not to know of the earlier works and said, "But how is it possible that such examples have not been put to use, how could they even have been completely forgotten." [Translated from the French] Ref. Bourdel and Th. Leroy "L'evolution de l'Organisation Scientifique en France." Méthodes, November, 1938, p. 324. How could Taylor not have known of earlier experiments when they were so widely publicized and Taylor himself had had earlier writings in English, German, and French studied for usable material. Ref. Taylor Principles of Scientific Management, op. cit., p. 54.
The preceding statements may sound like harsh words to some. But let those who doubt the truth of these statements study carefully the works of Taylor and those prior to him and they undoubtedly will come to similar conclusions. They will be forced to agree with those unheeded voices who, even in Taylor's time, said that there was very little or nothing new in scientific management.\textsuperscript{43} Needless to say, this is a subject of sufficient importance to the history of management to require more research and evidence than can be presented in this dissertation. When and if the truth is fully known, we will have a much better understanding of the historical background out of which our present management concepts have grown.

It is important that one understand this background of Taylor's work in order to properly evaluate the possible influence Babbage might have had on Taylor. It has been said that Taylor "never read Babbage."\textsuperscript{44} This is doubtful, for Frank Gilbreth certainly knew of Babbage and may have called Taylor's attention to Babbage's works.\textsuperscript{45} Also as early as 1904 Babbage's On the Economy of Machinery and Manufactures was favorably noted in the management literature\textsuperscript{46} and thereafter in such books


\textsuperscript{44} Urwick, op. cit., p. 28.

\textsuperscript{45} See following section on Frank Gilbreth.

as The Primer of Scientific Management. Taylor was not only associated with the preceding book but participated in at least one discussion of Babbage's work. If Taylor was as avid a reader as he was supposed to have been, he certainly must have read Babbage's work, or works. Also the biographer of Taylor was so careful to claim no connection between Taylor and Babbage one wonders if there might not have been a close connection.

There were striking similarities between Babbage's and Taylor's works, such as in the science of shoveling. However, since other persons before and after Babbage expressed similar ideas, Taylor might not have obtained them from Babbage. He, for example, might have obtained these ideas from Jevons, some of whose work Taylor undoubtedly read.

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49 Sub-Committee on Administration of the American Society of Mechanical Engineers, op. cit., pp. 190 ff.
51 Ibid., pp. 219-221, 225-230, 278-279.
53 See Chapter VIII and this chapter.
54 Taylor must have read at least Jevons' book on Deductive Logic for it was required at Stevens Institute of Technology for entrance into the Sophomore class. Ref. Annual Catalogue of the Stevens Institute of Technology. Hoboken, New Jersey, 1863-1894, p. 13.
To properly evaluate Babbage's possible influence on Taylor it was essential to understand the source of some of Taylor's ideas. Since there were many, many works on industrial management concepts after Babbage there might have been many possible sources of Taylor's ideas. This dissertation has not attempted to study all of them. The following, however, will help answer the question of the possible influence of Babbage on Taylor.

One of Taylor's primary source of ideas was Dr. Robert Henry Thurston and the Stevens Institute of Technology. In June, 1883, Taylor received his Mechanical Engineering degree from Stevens Institute. At that time Stevens Institute was teaching some of the ideas for which Taylor was later given undue credit. Although Taylor apparently did not attend this school full time, he did read the required texts, pass their examinations, and learn enough to be granted a degree. The biographer of Taylor, since he was more interested in promoting Taylor than analyzing the sources of his ideas, naturally did not point out the importance of the Stevens Institute training.

55 Copley, op. cit., p. 127.
56 Annual Catalogue of the Stevens Institute of Technology, 1883-1884, op. cit.
57 Copley, op. cit., p. 127.
58 Copley, op. cit., p. 127, For an indication of some of the gross errors in the biography of Taylor see notes in Frank Gilbreth's personal copy in the Gilbreth Library, Purdue University.
One leading management historian said, "What Taylor did was apply the scientific method to the problems of business management." Note what was being taught at Stevens Institute while Taylor was a student there, "the application of scientific knowledge to familiar work and matters of business." Furthermore, note that while Taylor was a student Stevens Institute was teaching about machine-shop practice, precise measurements, machine design, tools, costs, planning, prime movers, and a "general summary of principle facts, and natural laws, upon the thorough knowledge of which successful practice is based; and general resumé of principles of business which must be familiar to the practicing engineer."61

Since 1871 Dr. Robert Henry Thurston had been a dominant figure behind this work at Stevens Institute. By the time Taylor was a student there, Dr. Thurston had founded The American Society of Mechanical Engineers.

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61 Ibid., pp. 21 ff.

Thurston, "Instruction in Mechanical Engineering," op. cit., pp. 188-196.

62 It is interesting to note that Dr. Thurston had been a professor in the area of natural philosophy at the United States Naval Academy prior to going to Stevens Institute. This was the area in which many important concepts relative to management were covered in earlier years. Ref. Durand, William Fredrick Robert Henry Thurston. New York: The American Society of Mechanical Engineers, 1929, p. 44.
Mechanical Engineers, was internationally known, and doing a great deal
to promote many ideas for which Taylor erroneously has been given
credit. In 1885, Dr. Thurston became Dean at Sibly College of Engineer-
ing at Cornell University and there continued his outstanding work
until his death in 1903. 63 He wrote some twenty-two books and about
670 articles and reviews in his lifetime. 64 Many were on strictly engi-
neering subjects but some covered such subjects as, business principles,
economics in manufacture, economics in engineering, engineering edu-
cation, evolution of education, industrial economics, scientific
method, etc. 65 It is impossible for this study to review all of Dr.
Thurston's work but what was reviewed showed that he was widely read,
an excellent student of the history of engineering education, and a
promoter of ideas such as the following:

The prosecution of scientific research in the various depart-
ments of engineering work; the creation of an organization that
should give students an opportunity to learn the methods of re-
search most usefully employed in such investigation; the assist-
ance of members of the profession, and business organizations,
in the attempt to solve such questions, involving scientific re-
search, as are continually arising in the course of business....

The systematic instruction of students in experimental
work.

The use of a graduation thesis in which "in nearly all
cases, the student is led to make the investigation by the bent

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63 Ibid., pp. 95 ff.
64 Ibid., pp. 245-287.
65 Loc. cit.
of his own mind, or by the desire to do work that may be of service to him in the practice of his profession.66

He who would accomplish most in the profession of the mechanical engineer, or in the trades, must best combine scientific attainments—and especially experimental knowledge—with mechanical taste and ability, and with a good judgment ripened by large experience. He must be carefully, thoroughly, and skilfully taught the principles of his art in the technical school, and the practice of his profession in office or workshop.67

The first step in any such work is the careful collection of facts and the patient study of all phenomena involved, and the registry of such facts and phenomena in the most accurate possible manner, and so systematically and completely that they shall be readily and conveniently available, and in such shape that their values and their mutual relations shall be most easily detected and quantitatively measured.

In this work we need the aid of careful and precisely-directed observation, and if we can secure the assistance of men whose powers are exceptional, and whose skill has been perfected by training and experience, and who are prepared by habits of study to direct such effort and to supply the demand for the application of knowledge already acquired, we shall find our work immensely facilitated.68

We must learn to narrow the gulf which has separated men of business from men engaged in study, in experiment and in diffusing useful knowledge.69

66 Thurston, R. H. "Instruction in Mechanical Engineering," op. cit., p. 192-195. It is interesting to the history of management that Taylor probably began his metal cutting experiments at Stevens Institute as part of his graduation thesis, for the second portion of his thesis was "Experiments Made to Determine the Efficiency of Tare Boring Mill" Ref. Hayward, op. cit., p. 10.


69 ibid., p. 24.
We have especially to exhibit the fact that there exists between the man of science and the man of business a community of interests....

The mission of science is the promotion of the welfare, material, and spiritual, physical and intellectual, of the human race. It has for its purpose and its object the improvement, in every imaginable way, directly and indirectly, of the mind and the body, the heart and the soul, of every human being. It is charged with the duty of seeking the cause of every ill to which mankind is subject; of finding a remedy for every misfortune to which the race is now liable; of ameliorating every misery known to sage or savage, of seeking ways of giving to all every comfort and all healthful luxuries; of reducing the hours of toil, and offering to the relived laborer intellectual occupations that shall at once take from him all temptation to waste his life in indolence and dissipation and give him aid in his feeble efforts to climb upward into a higher life; of enlightening the world intellectually....

It is further evident that there must be inaugurated a system of cultivation of science that shall promote the advancement of scientific knowledge, and that shall aid in the application of science to the daily work of humanity.

The above evidence indicated that Dr. Thurston promoted many ideas for which Taylor was later given credit. Furthermore, note that between 1892 and 1896 Dr. Thurston wrote a series of articles and a book on the animal as a machine and a prime mover. In these Dr. Thurston referred to earlier studies on how much work men could do; such as the studies of Coulomb and others. It was probably from these, or other

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72 Ibid., pp. 243-244.

73 Durand, op. cit., p. 246.

74 Thurston, R. H. The Animal as a Machine and a Prime Motor,
similar references, that Taylor obtained his ideas for the science of shoveling, the pig iron experiments, and the law of heavy labor.

From the evidence studied for this dissertation it is certain that Taylor's ideas on these subjects and others were largely plagiarized. This was typical of Taylor, who was known for failing to give due credit to others and craving a great deal of recognition for himself, even to the extent of distorting the truth to his own advantage. 75

What then of the relationship between Babbage and Taylor? This research found that Taylor undoubtedly read Babbage but Babbage's work probably did not have much influence on Taylor directly. There were other, much stronger, but similar, influences on Taylor—such as the work of Dr. Robert H. Thurston.

Babbage's work might have influenced Dr. Thurston or some of the others who associated with Taylor; such as, William and Coleman

74 cont.

and the Laws of Energetics. New York: John Wiley & Sons, 1894, pp. 53 ff. Note that Thurston's title was similar to "Animal Strength" the title used frequently in earlier studies.

75 "Taylor was extremely egotistical and frequently vindictive. He craved personal credit and admiration to an extreme degree...." Ref. copy of letter from Fred H. Calvin, editor of the American Machinist to Margaret Ellen Hawley, April 6, 1927 in Gilbreth Collection, Purdue University.

Yost, op. cit., pp. 184, 198-203, 208-212, 220, 326.

A review of papers in the Gilbreth Collection and the Taylor Library will substantiate this statement even more.

76 There is no known record of Babbage's On the Economy of Machinery and Manufactures being used as a textbook at Stevens Institute although it was recommended as a text at least once. Ref. DeBow,
Sellers, Barcroft, Merrick, James Mapes Dodge, etc. No study was made of these possible connections, but it was noted that these people had more interrelationships through Philadelphia businesses or families than has normally been recognized. Also, their background of ideas which led to the scientific management movement has never been put in proper perspective. Babbage had connections with some of these men through the works of such men as Whitworth, but it is unnecessary to follow that train of development here for there were other more important influences of Babbage.

76 cont.


78 The important influence of the Franklin Institute, which was a continuation of the mechanics institute movement, has not been recognized. See Chapter VII on "Industrial Education."


79 See this chapter "Improving the Art of Manufacture."


Frank B. Gilbreth

Charles Babbage definitely affected later industrial management developments for he had a "great influence on" Frank B. Gilbreth, who in turn certainly made contributions to early twentieth century management. 30

This information was provided by the best possible source on this subject, the first lady of management, Lillian Moller Gilbreth. To the great credit of the Gilbreths it should be noted that they have certainly been more willing to give credit to others than some of those involved in the scientific management movement. Mrs. Gilbreth has made at least some of those who influenced Frank Gilbreth a matter of public record. Of those listed, Charles Babbage was the only one indicated as having had a "great" influence on Frank Gilbreth.

30 In the Gilbreth Library at Purdue University, Lillian Moller Gilbreth has added various pieces of information to the already valuable research material in this library. In one of the small card files there is a section on "Books which influenced F. B. G." Under this heading there is the following card. "Babbage, Charles: Great influence on F. B. G. Three books in library." The above idea has also been confirmed in private conversation with Mrs. Gilbreth.

Adam Smith's Wealth of Nations also influenced Frank Gilbreth. This reference card says "He read and reread it, purchased (and gave away) every copy he saw." From the copy of this book in the Gilbreth's Library it appears that Frank Gilbreth concentrated on the first portion of this book.

Although there are two copies of Babbage's On the Economy of Machinery and Manufactures in this collection, the original one of Frank Gilbreth's is probably not there. He usually made marginal notes in the important books he read, but neither book has these markings.
It is not known exactly how Frank Gilbreth's attention was called to the work of Babbage, but there are several possible ways this might have occurred. First, as a young man, Frank Gilbreth studied some technical subjects at night school in Boston and also had friends attending the Massachusetts Institute of Technology. Either of these might have called his attention to Babbage through classroom use or reference. Secondly, Frank Gilbreth was apparently an ardent reader, and rereader, of W. Stanley Jevons' book, *The Principles of Science, A Treatise on Logic and Scientific Method*. Frank Gilbreth's attention may have been called to Babbage's works through Jevons' various favorable references to Babbage. Third, attention may have been called through other writer's references to Babbage or a "chance" finding of Babbage's book.

The time when Frank Gilbreth began to become acquainted with Babbage's writings is not known. He might have known of Babbage's work before 1890, for one of the comments at the end of Gilbreth's copy of the above book of Jevons' is, "5 Jan./90. 5th reading of this great book." This is followed by the note, "1 May/92. 6th reading of this

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63 See earlier discussion in this chapter of W. Stanley Jevons.
great book. I find more in it than ever. I see much for future study in it. "84 Perhaps Babbage's ideas were one of the things Frank Gilbreth found in Jevons' book. 85

Although there have been various books written about the Gilbreths and some excerpts of their writings have been recently published, 86 there is no known research of the wealth of material in the Gilbreth Library at Purdue University or of the true part the Gilbreths played in the scientific management movement. 88 Until such a study is made it will be difficult to know Babbage's specific influences on the Gilbreths. 89 Such a study is needed to improve the

84 See footnote 81.

85 Personal correspondence with Mrs. Gilbreth indicated that Frank Gilbreth knew of both Jevons and Babbage when she first met him, (1903).

86 Gilbreth, Lillian op. cit.


88 Nadworny, Milton J. Scientific Management and Labor, 1900-1940: American Historical Study. Madison: University of Wisconsin, 1952, Ph. D. Thesis. This work begins to indicate more of the true part the Gilbreths played.

89 Frank Gilbreth could have visited with Babbage's son, Henry P. Babbage, for the son did not die until 1918. Furthermore, the Gilbreths might have come in contact with Henry P. Babbage at the
history of industrial management concepts, but that additional re-
search was too great to add to this study.

At least the following works by or about Babbage were known by
the Gilbreths and are in their library collection at Purdue Univer-
sity: On the Economy of Machinery and Manufactures, (two copies),
Passages from the Life of a Philosopher, and "Charles Babbage."

Many similarities of ideas between Babbage and the Gilbreths

89 cont.

Japanese-British Exposition of 1910, where he exhibited part of the
calculating machine he and his father, had worked on. Ref. Who Was
op. cit., p. 181.

90 Babbage, Charles On the Economy of Machinery and Manufactures.
London: Charles Knight, 1835 and 1846. The published catalog of the
Gilbreth Library lists only one of these volumes. Ref. Hepburn, op.
cit., p. 183.

91 Babbage, Charles Passages from the Life of a Philosopher.
London: Longman, Green, Longman, Roberts and Green, 1864.

Some of Gilbreth's marginal notes and markings in this volume are
interesting. Babbage's statement, "that occupation of the mind is such
a source of pleasure that it can relieve even the pain of a headache,"
apparently impressed Frank Gilbreth. (Ref. p. 111) Did this have any-
thing to do with Gilbreth's various means of educating his children?

Frank Gilbreth further noted Babbage's part in the formation of a
Society for the Promotion of Analysis. (Ref. p. 29) Did this have
anything to do with Gilbreth's helping to start the Society to Promote
the Science of Management?

Did Frank Gilbreth's noting of this phrase in Babbage, "a fair
day's wage for a fair day's work," have anything to do with its later
popular use? (Ref. p. 439)

92 Although the identification of this article is blocked out in
the Gilbreth copy it is, "Charles Babbage" Annual Report of the Board
of Regents of the Smithsonian Institution...for the year 1873.
were noted during this research but, in the absence of a complete study of the Gilbreth's works, these similarities were not enumerated here due to possible errors of either omission or commission.  

93 Babbage is quoted in at least three books by the Gilbreths and there are more areas of identity than these.


For the reference of further possible research on this subject it is of interest to note the following passages which Lillian Gilbreth apparently marked in her copy of Babbage's On the Economy of Machinery and Manufactures, which she received in 1911.

The muscles of the limbs employed have acquired a flexibility during their exertion, and those not in action a stiffness during rest, which renders every change slow and unequal in the commencement. Long habit also produces in the muscles exercised a capacity for enduring fatigue to a much greater degree than they could support under other circumstances. (p. 171)

Skill acquired by frequent repetition of the same processes.—The constant repetition of the same process necessarily produces in the workman a degree of excellence and rapidity in his particular department, which is never possessed by a person who is obliged to execute many different processes. (p. 172)

The division of labour suggests the contrivance of tools and machinery to execute its processes.—When each process, by which any article is produced, is the sole occupation of one individual, his whole attention being devoted to a very limited and simple operation, improvements in the form of his tools, or in the mode of using them, are much more likely to occur to his mind, than if it were distracted by a greater variety of circumstances. (p. 173)

When each process has been reduced to the use of some simple tool, the union of all these tools, actuated by one moving power, constitutes a machine. In contriving tools and simplifying
Frank Gilbreth was one who made himself thoroughly acquainted with the literature of management and could place many references to the classics without looking at the books.\textsuperscript{94} The Gilbreths knew where to find information and never gave up learning about it.\textsuperscript{95} One of their most fruitful sources of information was undoubtedly Babbage's \textit{On the Economy of Machinery and Manufactures}. At least through the Gilbreths, Babbage influenced twentieth century management concepts.

The great influence which Babbage had on Frank Gilbreth was one of the contributions Babbage's work made to the historical growth of industrial management concepts. The fact that Babbage had this "great influence" is sufficient to prove that those who proposed that "Babbage's work produced little subsequent impression" were completely in error.\textsuperscript{96}

There were undoubtedly many more facts and much information which could have been uncovered about Babbage's influence on the Gilbreths and others interested in management concepts. Likewise, there were

\textsuperscript{93} cont.

processes, the operative workmen are, perhaps, most successful; but it requires far other habits to combine into one machine these scattered arts. A previous education as a workman in the peculiar trade, is undoubtedly a valuable preliminary; but in order to make such combinations with any reasonable expectation of success, an extensive knowledge of machinery, and the power of making mechanical drawings, are essentially requisite. (p. 174-175)

\textsuperscript{94} Gilbreth, Lillian \textit{Quest}, \textit{op. cit.}, p. 33.

\textsuperscript{95} \textit{Ibid.}, p. 37.

\textsuperscript{96} Urwick, \textit{op. cit.}, p. 28.
many, many others besides Babbage who exerted important influences. To repeat one conclusion of this dissertation—much more research is needed in the historical background of industrial management concepts. Until that is done one cannot adequately answer many questions on various backgrounds of historical influences. However, this research has proved that Babbage, and many others, were not small, isolated, impractical cases with no influence on later developments but were an integral part of developments which have been progressing for hundreds of years.

**Improving the Art of Manufacturing**

Chapters IV and VII noted the improvements Babbage made in tools and machinery. Unfortunately, he left only one paper on this subject but, as early as 1823-4, he was having special machinery constructed for work on the Difference Engine. Throughout his life Babbage continued to work and experiment on new and cheaper ways to produce items and at various times was commended for "constructing, and in


many cases inventing tools and machinery." Some judged him to be "a wonderful machinist, probably the best in England." Babbage's influence, however, went beyond what he designed or constructed himself for he was in contact with such famous machine designers and mechanical engineers as Joseph Clement, Joseph Whitworth, Henry Maudsley, Byron Donkin, James Nasmyth, and others.

With the evidence available, it was difficult to determine the exact influence Babbage exerted on these men or vice versa. This, however, was known—Babbage characteristically was a strong advocate of standardization, a great perfectionist, and one who continually sought simpler modes of construction. These traits undoubtedly influenced others whose work along these lines did so much to improve English manufacturing in the middle nineteenth century.

It was about 1827 that Joseph Clement, while employed on the construction of the Difference Engine, began to use standardized screws

100 "Minutes of the Council of the Royal Society relating to the report of the Committee on Mr. Babbage's Calculating Machine, February 12, 1829," reported in The Times, London, No. 15,011, Friday, November 16, 1832, p. 3.


104 See Chapters II-IV.
with a definite number of threads per inch.\(^{105}\) Joseph Whitworth, employed by Clement on the construction of the Difference Engine until 1833,\(^{106}\) continued and improved on this idea and established the Whitworth thread as standard throughout England.\(^{107}\) It is known that Babbage later encouraged Whitworth in his standardization movement\(^{108}\) and it would not be surprising to find that from the beginning Babbage was behind this standardization work of both Clement and Whitworth.

Joseph Clement was also one of those who helped achieve the adoption of the involute form of gear tooth.\(^{109}\) Previously, the epicycloid had been frequently advocated as the correct tooth form.\(^{110}\) It is doubtful that Clement had sufficient mathematical background to analyze the difference between these two and to realize the need for the involute form. Babbage, with his knowledge of mathematics, probably played a part in convincing Clement of the proper tooth shape;\(^{111}\) and Clement in turn aided others. Thus better machinery resulted from

\(^{105}\) Babbage, Henry P. op. cit., p. 340.

\(^{106}\) Loc. cit.


\(^{108}\) Buxton, op. cit., p. 47.


\(^{110}\) Ibid., pp. 79 ff.

\(^{111}\) Babbage, C. Passages, op. cit., pp. 43-44.
the improved gearing. Clement made many other improvements in tools and machinery. It is not known what part Babbage might have played in their improvement or how much of it was done for work on the Difference Engine. 112

Babbage undoubtedly helped train Joseph Whitworth, who worked as a young man on the Difference Engine. 113 It was sometimes said, "Babbage made Clement, Clement made Whitworth, and Whitworth made the tools." 114 It was further reported that Joseph Whitworth "later amassed a fortune by utilizing as a mechanical engineer, the training which he got from Babbage." 115

In 1830, while working for Clement, Whitworth made the first "true" plane surfaces ever produced. 116 After this it was relatively easy to produce additional true flat surfaces. "The old method of producing true planes was that of grinding the surfaces of plates alternately with emery powder and water, which was imperfect as it was


For discussion of Clement's part in the construction of the Difference Engine see Chapters III-IV. For possible connection between the Difference Engine and Clement's work see Babbage, Passages, op. cit., p. 46.


Whitworth showed how the last operation actually destroyed any true plane and how true planes could be produced by a final operation of scraping. The realization of the flaw in the previous methods might have come from Babbage, who in turn might have learned it from Herschel. It is doubtful if Whitworth's education had taught him that two plane surfaces rubbed together with abrasive produces two conical surfaces. This, however, was known to Babbage and undoubtedly was one of the ideas known by the great telescope maker, William Herschel. Thus, this knowledge was probably conveyed from the astronomers to the workshop and added greatly to the art of manufacturing.

Another achievement of Whitworth's was to construct extremely accurate measuring devices. In some of these he used ideas previously employed by Babbage as early as 1830. This equipment to measure in ten-thousandths of an inch gave still more impetus to the advancement of the mechanical and manufacturing arts.

117 Ibid., p. 219.
118 Whitworth, op. cit., pp. 3 ff.
119 See Chapters II-IV and VIII for Babbage's relationship to the Herschels.
120 Babbage, C. Economy, op. cit., pp. 67-68.
121 Whitworth, op. cit., p. 42.
Whitworth was also noted for his work on firearms and the encouragement of industrial education,\(^\text{124}\) both of which had also been of interest to Babbage. Furthermore, Whitworth's developments were frequently based on lengthy experimentation,\(^\text{125}\) similar to that which Babbage practiced and advocated. Whitworth's works were internationally recognized and his writings were widely read by leading engineers.

One of Whitworth's publications reported, in 1858, on various manufactures in the United States. Included in this was a detailed tabulation of the routing used in one factory to produce musket stocks. This listed not only each operation but tabulated the "time occupied" for each operation in minutes, seconds, and quarter seconds. It further indicated the "total time of machine operations, total time of hand operations, allowance for double simultaneous operations... [and] Man's time taken to the whole operation of making a complete musket stock."\(^\text{126}\)

Dr. Robert Henry Thurston knew and admired Whitworth's works and perhaps taught some of these ideas at Stevens Institute to a student named Fredrick W. Taylor.\(^\text{127}\) This illustrative routing and operational times quoted by Whitworth adds strength to the following statement by

\(^{124}\) Ibid., pp. 232 ff.

\(^{125}\) Jeans, op. cit., pp. 217 ff.

\(^{126}\) Whitworth, op. cit., pp. 162-164.

\(^{127}\) See earlier section on Fredrick W. Taylor.
William T. McCruder. "For your information Time Studies were far from new when I entered industry in 1881. It was the publication of Mr. Taylor's papers before the ASME which called special attention to time-study work..." Perhaps Taylor even plagiarized his ideas on time study.

Men such as Clement and Whitworth certainly helped advance the art of manufacturing. Babbage too made his own contributions and, through his influence on men such as Clement and Whitworth, he may have made great contributions to the art of manufacturing. Babbage, however, did not stand alone in this for there were many who preceded him as well as many who followed.

Invention...is a drama enacted on a crowded stage. The applause tends to be given to those who happen to be on the boards in the final act, but the success of the performance depends on the close cooperation of many players, and those behind the scenes.

And who is to say which one should receive the greatest applause?

128 Letter from William T. McCruder to Margaret Ellen Hawley, April 6, 1927. Copy in Gilbreth Collection, Purdue University.


Significance of Charles Babbage in management history

These last two chapters have indicated that Babbage's *On the Economy of Machinery and Manufactures* was based on a considerable amount of prior study and yet this work was influential throughout the nineteenth and into the twentieth century. Why was this true? Why has this book, which contained few new facts, been significant in the history of industrial management concepts? ¹³¹

Briefly, Babbage's *On the Economy of Machinery and Manufactures* is significant to management history for the following reasons:

1. it was one of the earliest recognized books dealing with industrial management concepts; ¹³²
2. it influenced others in their industrial management ideas and actions; ¹³³
3. it expressed many ideas which

¹³¹ One critical reviewer was quite right when he wrote, "The book does not contain, so far as we can discover, a single sticking or novel fact." He, however, was just as wrong when he further implied that no one would remember or read the book in later years. Ref. "Babbage on Machinery and Manufactures." *Edinburgh Review*, LVI, January, 1833, pp. 313-332.


Thompson, op. cit., pp. 5 ff.

Urwick, op. cit., pp. 20 ff.

¹³³ See, for example, this chapter on "Frank B. Gilbreth."
have continued or became prominent in industrial management; it provided a connecting link between the past and the present in management.

This book achieved this place of importance for the following reasons: (1) the title contained two words which continued to be meaningful—economy and manufactures; (2) the wide circulation it originally received made copies relatively accessible to later readers; (3) the general plan of the book was one of broad coverage of basic ideas and principles and not minutiae of operating detail; (4) it combined ideas from economics, natural philosophy, mechanics, statistics, the physical sciences, and current practices; (5) the writing style superbly expressed ideas clearly and concisely.

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134 See Chapters V and VI. The considerable number of important ideas covered by Babbage makes this book significant.

135 See Chapters VIII and IX.

136 To some this may seem unimportant, but if the contents of On the Economy of Machinery and Manufactures had borne a title similar to some of Babbage's other books they probably would not have received nearly as wide recognition later. See for example books such as The Exposition of 1851 or The Ninth Bridgewater Treatise which give little or no indication of their contents to later researchers. Ref. Chapter IV.

137 The inaccessibility of some works has made it very difficult to obtain them for analysis as to their true content; for example, the work of Perronet. Ref. Chapter VIII. Babbage's book, however, can be found in many libraries of the United States.

138 This not only added to the stature of the book but made less chance for obsolescence of the material with technological progress.

139 This was one of the few books to do this and thus had appeal to many groups.

140 This was a great factor in the book's immediate and continued
the illustrations chosen were largely practical and included some which later grew in prominence; the entire work was essentially practical and in accordance with the trends of the times; Babbage used his imagination and foresight to challenge the reader; and the period in which the book was written helped it receive wide circulation and was also recent enough to include ideas and vocabulary meaningful to current concepts.

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success. It helped the work receive many excellent reviews and also made it very quotable and readable in later years. Ref. Chapters V, VI, and IX.


"Passages from a Philosopher's Life" Littell's Living Age, Third Series, XXVIII, 1865, p. 587.


If Babbage's illustration of the science of shoveling had been part of On the Economy of Machinery and Manufactures instead of in The Exposition of 1851, it might have received much more prominence.

The work does not deviate sharply from the dominant trends in power as did the work of Karl Marx. It did spell out profit sharing more than previously covered, but even then did not deviate wholly from existing thought. Ref. Chapter VI.

See for example "Future Prospects of Manufactures," Chapter VI.

See Chapter VIII. Also note that Babbage could talk about use of steam engines, etc. which were coming into prominence.
Also, of interest to this study, were the reasons why Babbage's work, and other early works, did not receive more recognition and true perspective from management historians. The reasons for this were as follows: (1) there was never any biographer of Babbage; (2) he never established a school of thought or body of theory to perpetuate; (3) after its initial success Babbage did little to revise the book; (4) Babbage's interests became concentrated elsewhere very soon after the publishing of On the Economy of Machinery and Manufactures; (5) Babbage's other activities and obsessions caused him to lose stature rather than gain it; (6) F. W. Taylor and his followers completely distorted the true picture of management history.

145 Frequently the work of one man is placed out of proper context with another because of someone who makes available information about one but not the other. Compare for example the writings about Sir Humphry Davy and William Hyde Wollaston with their actual lives. Note that a biography of Babbage was written but never published. Ref. Buxton, op. cit., p. 43.

146 Babbage's work was probably a much more accurate description of actual conditions than Ricardo's, but Babbage did not have a body of theory as Ricardo or Malthus did, which could be taught and argued about.

147 Practically all the revision occurred in 1832. No further editions even were made after 1835, although there were reprints. If Babbage had made slight revisions every three to five years and issued new editions, his work might have continued to receive more sales. Ref. practices of book publishing, also, see "Evolution," Chapters V and VI.

148 See Chapters III and IV.

149 Babbage's obsession on his calculating machine, the British government, and finally street noises did his prestige much harm. Ref. Chapter IV.

150 See Chapters I, VIII, and IX.
and (7) there never has been any extensive or adequately published research of management history for the time prior to the end of the nineteenth century.

The preceding research of the life and works of Charles Babbage was by no means a complete answer to the need for a good analysis of the historical development of industrial management concepts. It is hoped, however, that this study has provided sufficient information, not only on Charles Babbage but on other aspects of management history, to indicate the need and opportunity for much further research in this important background of our ideas. If others will add further information and analysis, we may yet achieve a constructive understanding of our past and use it for a better building of our future.

Chapter Summary

It was known that Babbage influenced such areas as mathematics, calculating machines, and scientific societies, but this chapter studied his influence in the area of industrial management. The previous chapter noted the considerable amount of unrecognized study done prior to Babbage, and the research for this chapter found that this trend continued with much being done between the work of Babbage and F. W. Taylor. No attempt was made to analyze all these developments, but the question answered was whether or not Babbage's work produced little subsequent impression.

Various popular authors such as John Stuart Mill, W. Stanley Jevons, and Alfred Marshall gave favorable recognition to Babbage's
work. Mill referred to Babbage’s comments on increasing production; division of labour and the various advantages of it; economical distribution of labour; problems of organizational and operational expansion; and profit sharing. Jevons made many favorable references to Babbage, including his comments on Coulomb’s studies of men carrying loads, causes of fatigue; and the science of shoveling. Alfred Marshall frequently quoted Babbage’s passage on using the proper amount of each class of labour and noted similarities between Taylor’s and Babbage’s works.

These three proved that many ideas Babbage expressed did not die out. The research was directed to a determination of Babbage’s influence on such men as F. W. Taylor and Frank Gilbreth.

No proof was found whether or not F. W. Taylor was influenced by Babbage. However, it was found that there was a great deal of plagiarism and misrepresentation in Taylor’s work and that he was credited with much originality which he did not deserve. Many of his ideas were learned at Stevens Institute of Technology and from Dr. Robert Henry Thurston; such as, the application of scientific method to business, studies of shoveling, etc. There were also others whose influence on Taylor and the scientific management movement have not been properly evaluated. Babbage might have influenced these men, but, as far as Taylor was concerned, there were other similar but stronger influences.

Babbage definitely had a great influence on Frank Gilbreth. The year Frank Gilbreth knew of Babbage’s work was not determined, but it
was probably before 1900. This might have come about through Jevons' references to Babbage. Although many similarities between Babbage and Frank Gilbreth were observed, they were not recorded here due to the absence of a good study of the Gilbreths' works and their true contribution to industrial management. There is no doubt, however, that Babbage's work continued to be influential throughout the nineteenth and into the twentieth century.

Another important influence of Babbage was his direct and indirect contributions to the art of manufacturing. Through men such as Joseph Clement and Joseph Whitworth, Babbage's influence on standardization, improving tools and machines, and providing simpler and cheaper modes of construction might have been very great. Through these men, Babbage probably influenced the use of standardized screw threads, true plane surfaces, involute form of gear tooth, more accurate measuring devices, and industrial education. Whitworth's writings also helped advance mechanical engineering, and, as early as 1858, he cited detailed examples of routings and operation times in minutes, seconds, and quarter seconds.

With all the developments which occurred after Babbage, who can say the exact influence which he had? But of this there is no doubt, he was influential in many areas, including industrial management.

Babbage's *On the Economy of Machinery and Manufactures* is significant to management history for it was one of the early recognized works; it influenced others; it included many ideas pertinent to management; and it provided a connecting link between the past and
the present. The book achieved this importance for the following reasons: usable title, relatively available, broad coverage of basic ideas and principles, ideas gathered from many fields, superb writing style, practical and significant illustrations, fitted trends of times, good foresight and imagination, and recent enough to include currently meaningful ideas.

Babbage's work did not receive greater recognition for there was no biographer of Babbage; he established no school of thought or body of theory; little revision was made of the work; Babbage's interests were concentrated elsewhere; Babbage's other activities and obsessions lost him stature; F. W. Taylor and followers distorted management history; and there has never been any adequate research published on the history of management prior to the twentieth century.

Much more information and analysis is needed of our management heritage so that we may achieve a more constructive understanding of our past and build a better future upon it.
CHAPTER X

SUMMARY AND CONCLUSIONS

Introduction

The objective of this dissertation was to evaluate the contributions made by Charles Babbage to the historical development of industrial management concepts. Such a study was needed to help build a better understanding of the heritage out of which today's management ideas have grown. Charles Babbage was chosen as the focal point of this study because he has been increasingly recognized as an early contributor to management concepts; because he wrote on a wide range of management topics; and, although his ideas had been evaluated as being far in advance of their time, a comprehensive study of his true place in the history of management concepts had never been undertaken.

To accomplish the above objective a study was first made of the events of Babbage's unusual life to determine the context out of which his ideas grew. This was followed by a presentation of his industrial management concepts, which were largely found in his book, On the Economy of Machinery and Manufactures. Then, in order to evaluate properly Babbage's contributions to management history, a study was made of management concepts prior to Babbage and of people and circumstances which influenced him. This was followed by an analysis

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1 Babbage, Charles On the Economy of Machinery and Manufactures, Charles Knight, 1832.
of Babbage's influence on others and on later industrial management developments.

As a result of this study, not only was new information presented on Babbage's works and contributions, but also gross errors were found in the classical interpretations of management history. Many new and interesting facts of Babbage's unusual and fascinating life were found, but the interested reader should turn to Chapters II-IV for these. For a summary of the major contents of On the Economy of Machinery and Manufactures see Chapters V and VI. Below is a summary of the findings and conclusions pertinent to Babbage's contributions to the historical development of industrial management concepts.

Charles Babbage the Individual

Babbage spent only a small portion of his life and energies writing about industrial management concepts.

Babbage was active in an unusual number of things and wrote on many subjects, many of which had no direct relationship to industry or to management.2 His writing in the area of management began in 1829 with the introductory essay in the Encyclopedia Metropolitana, "Introductory View of the Principles of Manufactures." Babbage's writings on management practically ceased after the second edition of On the Economy of Machinery and Manufactures which was published in

2 See Chapters II-IV.
1832. Following this he did practically nothing to enhance his reputation in this area. However, almost incidental to several other writings were several items of interest to management history, such as his paper on tooling, and the illustration of the science of shoveling in *The Exposition of 1851*.

Babbage was essentially practical in his ideas but had deficiencies in his personality and his dealings with people.

Babbage was a leader of ideas but not of men. His ideas did not come from an ivory tower for he was essentially interested in analysis based on facts. Many of his actions and writings such as the following substantiate this: founding the Analytical Society, study of magnetism, principles for producing the most usable mathematical tables, constants of nature and arts, method of observing factories, founding statistical societies, etc. Babbage, however, had deficiencies in his personality which limited his success. He did many things to make enemies and frequently lacked tact, humility, and compromise. This, plus his great craving for recognition, prevented him from accomplishing even greater things.

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3 See Chapters III and IV.
4 See Chapter VII.
5 See Chapters II-IV.
Babbage's obsession with his calculating machines detracted from his recognition as the author of "On the Economy of Machinery and Manufactures."

In 1832 Babbage's reputation as a scientist probably aided the initial widespread acceptance of this book. However, his calculating machines were already becoming an obsession with him, and within a very few years after the publication of this book his activities regarding them hurt his reputation. Many of Babbage's writings and publicity after 1832 were for the purpose of calling attention to his calculating machines in order to gain financial support for their construction. He became so persistent in this that it detracted from his other accomplishments. Even today Babbage is most widely known as being the forefather of the modern digital computers.

Babbage's actions in the later part of his life did much to hurt his reputation.

Babbage became so obsessed with the ideas of his calculating machine, his hatred of the English Government, and his feuds with Richard Sheepshanks and the street noise-makers that he lost the respect of many. If Babbage had not carried out such activities detrimental to his onetime high reputation, he might have received much more recognition in later years. His reputation was probably at its

6 See Chapters III and IV.
height when he wrote *On the Economy of Machinery and Manufactures*, but when he died forty years later his antics had made him the laughing stock of many.\(^7\)

**Contributions to the Art of Manufacturing**

Babbage made **significant contributions to many areas**, one of which was the **art of manufacturing**.

Babbage, in addition to the area of industrial management, made contributions to such areas as the following: modern calculus, calculating machines, scientific societies, life insurance, logarithms, statistics, religion, lighthouses, and the art of manufacturing.\(^8\) Babbage advanced the art of manufacturing through his own work as a tool and machine designer and through his influence on such men as Joseph Clement and Joseph Whitworth. His influence probably extended to helping achieve standardized screw threads, true plane surfaces, involute form of gear teeth, more accurate measuring devices, and improved industrial education.\(^9\)

**Earlier Studies of Management Concepts**

Many **significant studies of industrial management problems were**

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7 See Chapters III and IV.
8 See Chapters II-IV.
9 See Chapter IX.
made prior to Babbage's "On the Economy of Machinery and Manufactures."

Management historians have taught that little or no study was
given to management problems prior to the end of the nineteenth
century. This research found these teachings to be grossly in error
for a great many studies of industrial management problems were made
even prior to Babbage. In fact, so much earlier work was done that
this study could only sample it.

On the concepts of a fair day's work, or how much work a man could
do in a day, there were persons such as the following writing on this
subject: De la Hire, Bernoulli, Desagulier, Coulomb, Robinson,
Buchanan, Gerstner, Welcher, Nordwall, Vauban, Christian, Nicholson,
Emerson, Leslie, Hachette, Morisot, Hassenfratz, Navier, Amontons,
Bouguer, Euler, Schulze, Sauveur, Belidor, and others. Not only did
many of these men study and experiment as to how much work men could
be expected to do in a day, but many intended their results to be used
in industry. Furthermore, these were not isolated, unrelated studies,
but were frequently interrelated with one testing and amplifying the
work of others. The above studies go back at least as early as 1699.

To show the merits of these earlier studies, excerpts from some
were presented. These not only showed a good understanding of manage-
ment problems but a high degree of similarity to later developments.
There were writings about optimum loads, fatigue, need for frequent
intervals of rest when doing heavy work, best physique to use on one

10 See Chapters I and VIII.
Many thousands of people were studying management problems and the application of scientific principles to industry long before the advent of "scientific management."

The previously mentioned studies were reported in many industrial books and popular industrial magazines, and were studied by many thousands of people in lectures and courses. The industrial education movement which was concerned with many of these subjects went back at least as far as the sixteenth century. By at least the eighteenth century there were leaders of engineering education, like M. Perronet, who made excellent studies of manufacturing. One of these by M. Perronet not only described the time of each operation but described methods, tools, materials, and costs for each process. The article even entered into product costing. Perronet also devised a means of measuring worker output which helped regulate their task and their pay.

There were various French, German, and English schools established which were for the purpose of using scientific instruction to improve
industry and manufacturing. With the work done by Professor Anderson in Scotland in the late eighteenth century the movement became a popular one and mechanics institutions spread rapidly throughout England and France. These institutions were established in most cities throughout England in the 1820's for the purpose of teaching the application of scientific principles to industry. In England by 1850 there were on record 610 of these institutions with over 100,000 members.

This movement spread to France in the latter half of the 1820's largely through the work of Baron Charles Dupin. In 1826 some 5,000 workers, foremen, supervisors, etc. in almost 100 French cities attended courses patterned after those established by Baron Dupin. These courses included ideas very pertinent to management. The work of Baron Dupin has not been recognized by management historians and a translation of some of his ideas is therefore presented in the Appendix. Baron Dupin covered topics such as the following: rhythm; the importance of the foreman knowing how to produce each job with a minimum outlay of money and energy; need for knowing how to apply intellectual faculties; importance of posture; improving wellbeing of working classes; proper tools; and the future prospects of manufacturing.

The records show that many thousands of people in England, France, Germany and the United States were actively studying management problems long before the advent of "scientific management."  

12 See Chapter IX and Appendix.
Earlier writings, events, and people influencing Babbage

The book, "On the Economy of Machinery and Manufactures," was built around Babbage's earlier essay, "Introductory View of the Principles of Manufactures."

Section one of the book contained almost no change from part one of this introductory essay. Part two of the essay was amplified and modified to form section two of the book. The changes made were the addition of new topics; amplification of earlier topics; more emphasis on the inductive approach; and modifications of the theoretical principles so as to conform more to practice. No significant changes were made after the second edition of the book in 1832.13

Factors which might have influenced the writing of this introductory essay were as follows: Babbage was a superb machinist and had visited many factories; two of Babbage's elder associates had been students of manufacturing; Babbage and many of his friends wrote other articles for the Encyclopedia Metropolitana; Dr. Gregory, the advisor to this encyclopedia, was a friend of Babbage; the general plan of the encyclopedia was conducive to using this type of introductory essay.14

13 See Chapters V and VI.
14 See Chapters III and VIII.
Babbage's book, "On the Economy of Machinery and Manufactures" and the earlier essay were based largely on previous writings and were influenced by many people and circumstances.

There were few, if any, new facts in this book or in the earlier introductory essay. Babbage drew material from such areas as mechanics, economics, statistics, the physical sciences, House of Commons Committee Reports, previous industrial writings and his own intimate knowledge of business and industry. He knew of many of the earlier studies, such as those of Coulomb. He undoubtedly knew of Dupin's work and probably was influenced by it in various ways. The industrial education movement which grew so rapidly in the 1820's also influenced Babbage and may have been a factor in his publishing On the Economy of Machinery and Manufactures for it provided a ready market for this book.

Other factors which probably induced Babbage to publish the book were as follows; first, Babbage had intended to deliver the contents in a series of lectures at Cambridge University, but published the book when the lectures did not materialize; second, Babbage's close friend, John Herschel, had recently published a very successful book on natural philosophy and Babbage decided to publish one on manufacturing like Herschel's.

Other people who influenced Babbage's ideas were Dr. William Hyde Wollaston and William Herschel—both expert scientists and students of manufacturing. John Herschel, the leading scientist of his time and close friend of Babbage, supported and influenced Babbage in many
of his activities. Further factors which influenced Babbage were the reform movement, and probably his economist friends, such as Richard Jones, Malthus, and Nassau Senior.15

Contributions of "On the Economy of Machinery and Manufactures"

"On the Economy of Machinery and Manufactures" probably represented some of the best management thought and practice in 1832.

Throughout Babbage's writings he was trying to express the best thoughts and practices as he saw them. Although a reformer, Babbage's ideas were usually very much in step with leading thinkers of his time and usually opposed by only the older, more conservative elements. Babbage was from the upper levels of society and intimately associated with a great many of the leaders of society, science, and the arts. He was interested in improving various aspects of science and industry but was not interested in a radical overthrow of the existing structure.

There is nothing to indicate that Babbage's thoughts were far in advance of his times in the sense that others were also thinking similar ideas. Even on the subject of profit-sharing, what Babbage proposed was being used in the Cornish mines and on whaling ships and had probably been discussed before a committee of the House of Commons.

15 See Chapters III, IV, and VIII.
Babbage collected the majority of his information not from theory or speculation but from actual observation, interview, and other writings. The result was a presentation of some of the best industrial management thought and practice in 1832.¹⁶

Contributions made to industrial management literature by the book, "On the Economy of Machinery and Manufactures" were as follows: the general plan of the book, the wide area from which ideas were drawn, and the superb writing style used.

One of the merits of Babbage's On the Economy of Machinery and Manufactures was the general plan of the book, which was to present the mechanical and economic principles relating to machinery and manufacturing. Furthermore, Babbage did not try to enumerate all the mechanical principles but only those of a broad over-all nature. For the economic principles Babbage considered not only the external political economy of the subject but also the internal economy of factories. Fortunately for those interested in industrial management, these economic principles were the ones to which he gave the most attention.¹⁷

Babbage felt that most people with a tolerable education could understand the general principles of manufacturing and their mutual relations. He presented the principles for these people, by avoiding

¹⁶ See Chapters II-IV, and VIII.

¹⁷ See Chapters V and VI.
technical terms, using concise language, and by supporting the general principles with facts, anecdotes, and excellent illustrations.¹⁸

On the Economy of Machinery and Manufactures is the first known book to have established this objective of presenting the general principles of manufacturing in such a broad coverage and yet in a non-technical fashion. Although there were probably no new important facts in the book the manner in which they were presented was new. Others had presented principles but none had drawn them from so wide an area. Frequently others had previously included similar principles in either limited articles or with much technical detail.¹⁹

Babbage's great breadth of interest and knowledge enabled him to assemble ideas from such areas as mechanics; natural philosophy; economics; industrial magazines and industrial books; the natural sciences; statistics; and current industrial practice. Previously each of these areas had covered principles relating to manufacturing but no one was known to assemble the best from each area as Babbage did. This was one of the contributions of this book.²⁰

A third contribution made by On the Economy of Machinery and Manufactures was the way in which Babbage used his superb writing ability to express ideas clearly and concisely. Babbage presented ideas and principles in an interesting and a very understandable manner. This

¹⁸ See Chapter III.
¹⁹ See Chapter VIII.
²⁰ See Chapters II–VI.
not only helped make the book usable to a great many people but also made it easily quotable, which in turn helped perpetuate Babbage's name and ideas. 21

Factors other than merit which helped contribute to the lasting influence of "On the Economy of Machinery and Manufactures" were its title, the attention given later to certain ideas, and the relative availability of the book.

Although this book did have many meritorious features to perpetuate its influence there were several, almost chance factors, which aided its long run influence.

First, the title of this book contained two words which continued to be meaningful to the researcher or reader. The words economy and manufactures continued to be ones which, in the title of a book, might induce someone to examine the contents. If this book had had a title similar to several of Babbage’s other books, such as The Ninth Bridge-water Treatise or The Exposition of 1851, its contents might not have been noted by nearly as many. Other works on industry and management which had usable contents but titles less meaningful were often forgotten, such as the case of Baron Dupin's work.

Another feature which helped perpetuate Babbage's name was the attention later given to certain ideas, such as the tabulation of the various operational times for pin-making. Since time study grew in

21 See Chapters V, VI, and IX.
popularity later, Babbage's tabulation was referred to as an earlier example of the timing of operations. If these times had not been presented in tabular form they might not have been referred to nearly as much in later writings. Part of the data came from the earlier work of Perronet, but Perronet did not present it in tabular form and thus it was not as easily recognizable or quotable.

A third feature which helped perpetuate the book's influence was the relative availability of it to later readers. The wide circulation it originally received in England, United States, France, Spain, Italy, and Germany made it available years later to those desiring to examine the contents. Throughout libraries of the United States the book is still frequently to be found. If it had received a limited circulation and were a rare book many fewer persons might have examined its contents.

Reasons why Babbage did not receive more prominence in management history were that he had no biographer; he established no school of thought or body of knowledge; he did not continue to write in this area; he lost stature in the latter part of his life due to other activities; and the true historical development of industrial management concepts became distorted in later years.

Frequently someone's work receives increased recognition through another's biography. If Babbage had had a good biographer his work

22 See Chapter IX.
might have received more attention. The only known biography of him, however, was never published.

Some works have been remembered because they established a school of thought or a body of theory. Babbage did neither of these. If, for example, he had given his work in lectures at Cambridge University as he had planned, he might have received more recognition.

Also, if Babbage had continued to write and revise his work his recognition in this area might have been perpetuated through a number of years. However, Babbage did very little writing in the area of manufacturing after his initial success in 1832.

As indicated under the earlier conclusion on Babbage as an individual, his other activities hurt his reputation shortly after On the Economy of Machinery and Manufactures was published. His reputation went down-hill most of the latter part of his life.

The last factor which has kept Babbage and others from receiving more prominence in management history has been the complete distortion of management history which was brought about by F. W. Taylor and his followers. Those who did see merit in Babbage's work could not recognize its true significance or the merits of others because they were so blinded to the truth by those who professed there was no significant work done prior to the end of the nineteenth century.23

Babbage's Influence on Nineteenth and Twentieth Century Industrial Management Concepts

23 See Chapter IX.
Popular writers called attention to Babbage's work throughout the nineteenth and twentieth centuries.

John Stuart Mill referred to the following ideas expressed by Babbage: manner in which tools and machines increase production; various advantages to the division of labour; problems of organizational and operational expansion; and profit sharing.

W. Stanley Jevons made many favorable references to Babbage, including comments on Coulomb's studies of men carrying loads; causes of fatigue; and the science of shoveling.

Alfred Marshall also frequently quoted Babbage, especially on using the proper amount of each class of labour. He further noted similarities between the work of Babbage and that of F. W. Taylor.

In the twentieth century there were references to Babbage in important industrial literature such as Deimer's 1904 biography of management literature, the Primer of Scientific Management, American Society of Mechanical Engineering committee report on "The Present State of the Art of Industrial Management," etc. Thus Babbage's work did not die out or become forgotten.

There were many other references to Babbage in the nineteenth century but the above are sufficient to indicate that his work continued to receive recognition in the nineteenth and twentieth centuries. 24

24 See Chapter IX.
Babbage's work had a definite influence on later industrial management developments.

Charles Babbage had a great influence on Frank B. Gilbreth, one of the leaders of early twentieth century management. The exact ways in which Babbage influenced Frank Gilbreth were not analyzed thoroughly due to the absence of a good study of the Gilbreth's works. Frank Gilbreth undoubtedly knew of Babbage's works early in his career and he might have learned many ideas from Babbage, for there were many similarities between Gilbreth's and Babbage's works. From the evidence there was no doubt, however, that Babbage did have a great influence on Frank Gilbreth.

There were many other possible channels of influence of Babbage throughout the nineteenth and early twentieth century but these were not analyzed due to the great amount of unsearched material relating to industrial management concepts. Babbage's influence on Frank Gilbreth was sufficient to show that his effect did not die out with the publishing of On the Economy of Machinery and Manufactures. Further research may reveal much more information not only about Babbage but about other important industrial management developments.25

Gross errors have been made in interpreting the work and contributions made by Fredrick W. Taylor.

25 See Chapter IX.
Although Fredrick W. Taylor probably read Babbage's book, there was no evidence found to prove that Babbage did or did not influence Taylor. However, management historians have made gross errors in evaluating Taylor's work.

Instead of Taylor's work being highly original, there was much plagiarism and misrepresentation in it and about it. Many of the ideas credited to Taylor actually came from such places as the Stevens Institute of Technology and such persons as Dr. Robert Henry Thurston. Taylor was a student at Stevens Institute where Dr. Thurston was a leading scientist and a promoter of such ideas as improved machine-shop practice, tools, machine design, costs, planning, principles of business, scientific method, careful and precisely-directed observation, the importance of applying science to business, etc.\footnote{26}

Ideas promoted by Taylor such as the science of shoveling, the pig iron experiments, and the law of heavy labor were undoubtedly a plagiarism of earlier studies written about by such men as Jevons, Babbage, Coulomb, etc.\footnote{27}

Taylor was known for craving a great deal of recognition for himself, even to the extent of distorting the truth to his own advantage. In so doing he not only distorted his own merits but he and his followers have distorted the true historical developments of industrial management concepts.\footnote{28}

\footnote{26 See Chapter IX.}
\footnote{27 See Chapters VII-IX.}
\footnote{28 See Chapter IX.}
There has been a much greater evolutionary development of industrial management concepts than management historians have realized.

There were many studies of industrial management problems long before Babbage. Babbage was influenced by some of these and in turn influenced later developments. The work which was supposed to have established the foundation of industrial management, that of F. W. Taylor, was actually based on earlier developments to a much greater extent than has ever been adequately realized by management historians. 29

There is need for a study of the true historical growth of industrial management concepts.

This research has studied only a small segment of management history, but in so doing has found that gross errors have been made not only in respect to Charles Babbage, but on the true historical growth of industrial management concepts. There is a wealth of unstudied material which can add greatly to our understanding of the heritage out of which today's industrial management concepts have grown. If we are to use historical perspective as one means to analyze and improve today's management concepts, much work needs to be done to improve our knowledge of the true historical growth of industrial management concepts.

29 See Chapters I, VIII, and IX.
APPENDIX

The following is a preliminary analysis of some of Baron Dupin's ideas, relevant to industrial management, as translated from his Géométrie et Méchique des Arts et Métiers et des Beaux-arts. Paris: Bachelier, III, 1826.

Second Lesson. Concerning the sense of hearing considered as an instrument of measurement, and of the direction which it serves to give to the strength of man. (pp. 41-72)

In civilian workshops I have also found many advantages in cadencing a group, or a number of movements. For example, when blacksmiths assemble to beat a piece of iron on the same anvil, they hit with regular and determined strokes, which not only prevents accidents through the clashing of hammers, but seems to diminish the fatigue of the work.

When a worker is given a task which consists of continuous repetition of the same movement, he soon develops movements of a constant time duration. This has several advantages. One of the first advantages is that it is not necessary to use the same degree of force all of the time, and consequently there is time for [one's] strength to be recovered. Another advantage which is important, but less noticed, is the impression of time which is transmitted to our senses
by the regular repetition of the same movement; with marvelous facility our organs abandon themselves to this repetition which can help them to recover to a surprising extent. This is the principle advantage that men have found in the division of work for the execution of jobs in industry.

Music has an effect on rhythmic movements of parts of the human body; for instance, when a man walks down the street and hears the beating of a drum, his step will either slow down or speed up to fit the music. When musicians play under my windows I often find that my writing begins to keep time with the music. Also various musical tones can have different effects on emotions of those who hear it.

Among people who cultivate the arts and crafts, very few are called upon to make demands through the eloquence of their voice, to please through their utterances, and to induce action by their language...For some men there is a vigor of accent, appearance and posture, which commands for him in his profession, an esteem that cannot be lightly contested. There is a noble simplicity which is fitting the industrial head, which will always earn him a place which he has a right to obtain in the ranks of society.

There is another tone which is fitting to the foreman, which will cause him to be obeyed, respected and beloved by his workers. In France, we often see foremen in workshops or factories who become too familiar with their inferiors, and who make them listen to long unceiled speeches, and useless explanations which have no real meaning. We also see them pass from an indecent familiarity to the outburst of
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an injurious anger, to be carried away without reason, and to make the whole establishment resound with their cries, for motives that are often quite frivolous. Precise, brief, simple orders, that is what is fitting in every case to a reasonable and logical authority; explanations which are always clear, heard as often as necessary, and never more than that. Finally, I repeat, never any anger, never any cries, never any outbursts, and above all never any blows; to strike an artisan, is to degrade the dignity of man, it lowers him to the lowest level of servitude. Show the worker what he is doing wrong; furnish his punishment coldly: he will not complain; and when he sees that your watchful attention has returned after the correction of the damage and of the offense, he will like you doubly well; both for your pardon and for forgetting the fault. This is what I do not fear at all to call the eloquence of industry; that which prevents disorder and difficulty, at the same time that it earns for the overseer the affection and the devotion of all the employees.

When the workers see that their foreman and his principle helpers only speak when necessary, they naturally imitate them. A remarkable silence becomes established in workshops. Each person pays attention to his work. Since attention is not distracted, the artisan's thoughts concentrate more strongly on the work which he is executing. Ideas for improvement or simplification arise easily from this concentration of thought. Thus the art should advance more rapidly, more work should be done in the same time, and the work better executed in workshops which are not like a fruit market,...When I visited an industrial
establishment of England I was always surprised by the silence. In the civilian workshops and in the government arsenals, in the constructions of the military and the merchant marine, one sees everywhere workers who are occupied only with their own work, not even turning their heads to look at a visitor. In the civilian crafts, this silence has economy as its principle advantage; in the military arts, it often has victory as its results.

The feeling of rhythm and of measured time, of which I have already spoken to you, contributes to relieving the fatigue of work, of combat, and of marching; roads seem less difficult or less unpleasant to the soldier when his step is lifted by the sounds of the drum or of music, and his love of battle is re-doubled by the sound of war-like instruments. The laborer who breaks the earth with the plowshare feels the weight of his work diminish when he accompanies his step with the rhythmic sound of his voice. By singing, the sailor charms the boredom of navigation, and diminishes the fatigue of maneuvering. Finally, the most mechanical artisans seem to relieve the boring monotony of unvarying, repetitive movements. Thus a melody arouses the intelligence and affections of the soul of those who work without end with their bones and muscles...to fabricate continually the same products of industry.

In those works which require the assembly of a large number of workers, the men need, in order to exert their efforts at the same time, to hear a rhythmic song from one of their companions. That is how music presides at the work of the arts.
Third Lesson, Physical Strength of Man (pp. 73-104)

Man cannot work, that is to say employ his strength at some useful task, except for a short period of time. He needs to regain his strength through drinking and eating, as well as through sleep, and often even through rest while he is awake.

Coulomb, a well-known wise man, who made extremely interesting researches concerning the strength of man, and of whom we are going to speak in detail, was unable to find a porter who wanted to cover during a day more than six trips, carrying from one house to another, at a distance of two kilometers, furniture of a weight of 58 kilograms, each load.

The total quantity of daily work is then far from remaining constant, as Daniel Bernouilli, the well-known geometer and very ingenious physician, had thought.

Coulomb was the first to discover the very great difference which exists in the total quantity of work....

Up to the present time, we still have to look into the matter of a large number of researches which are of great interest to the work of the mechanical arts. It is of great importance for the foreman or the director of the factory, whatever type it is, to produce each job with the least outlay of money possible. Thus, it is necessary for him to understand well the means by which he can, in any circumstance, produce the desired effect with a minimum of energy.

These things should be considered for a man walking up an incline. Is it more advantageous to conserve or maintain a constant slope and
to cause the pedestrian to take certain and more frequent rest according to his approach to the end of his route? Or would it not be better, in order to diminish the fatigue of the person who is walking, to make the incline a bit more steep toward the bottom and a little less inclined toward the top of the slope? By this last means, the pedestrian consumes a greater quantity of action to produce the same effects, and it seems that more and more frequent rest period are of more value than variations in the slope of the route.

When a man covers a horizontal path he could, if he judged it more advantageous, force his steps at the beginning of the day, slow down a bit toward the end and consume less strength in the time when he is more worn out. However, the experiment [of Coulomb] shows that this is not the best system of walking. Men who make the longest journeys moderate their steps from the very beginning and maintain it with regularity, taking rests as soon as they feel the need. They follow this system on horizontal routes and even on routes which are more or less inclined: just so the slope does not go over certain limits.

One of the worst means of employing a man is to have him climb with a load on his shoulders, on his head, or on hooks. This type of work which is often used in cities, because it does not require any machine apparatus should never be used in the workshops where it is desired to execute continuous works with economy and speed.

Here we clearly perceive a great advantage in the use of machines. Since man can furnish his day's work in quantities which are quite
different...For mechanical means do not create energy, they can only economize and distribute judiciously and advantageously the energy which they have to dispose:...

The best way for a man to raise a load to a given height, is to climb up himself without any weight, and to use the weight of his body as a motor force.

Coulomb calculated in a most ingenious manner the useful effect of a worker employed at spading the earth. (From his calculations it is seen that) the employment of workers for breaking up the earth with a spade is one of the most costly; it is only best in work in which great care is needed such as that of gardening, where the enormous expense of human energy is compensated for by the intelligence of which the work is applied and varied.

One of the most important considerations in using the strength of men, is the speed with which each man can execute the various types of movement. There is a velocity which, when once past, a man is incapable of producing any useful effects; because all of his muscular force is dispensed for the forcing of the various parts of his body to such movement. Accordingly, as the movement is slowed down, the man becomes more capable of producing a greater useful effect. In such a manner we arrive at the maximum useful effect. When, later, the man diminishes the amplitudo of his movements, he can undoubtedly produce greater pressure and greater shock; but the increase does not compensate for the diminution of speed. That is why the total quantity of movement decreases instead of increases.
Mr. Robertson Buchanan compared the action of four men; the first who was turning the hand crank, the second who was rowing, the third who was moving the lever of an ordinary pump, the fourth who struck a bell, and all of them working during a period of four seconds.

It is not only in the professions of day laborers that it is essential to obtain the maximum animal force that man can expend in a day's work. In professions of artisans, and with even greater reason in those of artists, the best means of employment of man consists more in an intelligent application made without loss of time, with a more or less large portion of physical force. The improvement of industry increases the number of professions in which it is necessary to make a greater use of the intellectual faculties and a lesser use of physical energy. To muscular work, which resembles the work of the ox, ass, or horse, man adds the ability of sight, hearing, touch, smell, and taste, guiding the perception of these senses with all the faculties of his intelligence. If he uses an observing mind, he procures knowledge of a great number of results which become a sure guide for him: this is what is called acquired experience, an acquisition so precious to the arts.

Whatever the applications may be that one wants to make of the strength of man in the works of the arts, it is necessary to avoid, with the greatest care, the subjugation of workers to forced positions which they must hold over long periods of time. These postures end by causing deformities, chronic illness or infirmities.
Almost always, with a bit of observation and talent, it will be found possible to modify the postures required of the workers, so that they may have a comfortable position for their work. It is certain that this comfort itself will permit them to produce a greater useful effect. Thus, while appearing to be giving attention to the welfare of the workers, the foreman or the manufacturing head will have worked for himself while serving humanity.

Lesson Four - For the Increase and the Better Application for the Strength of Man (pp. 104-136)

Let us examine how to increase the absolute strength which a man can use in the works of industry, and how to use this strength with the consistency, speed, and the most advantageous precision. Let us show how these results may be obtained by a happy combination of intellectual strength with physical strength, and what fine results one may expect, in either sex, to the advantage of the well being of the human species, and, at the same time make the working class happier and more moral.

From the age of five or six years old, children are employed in the works of industry. Occupations are entrusted to them which require very little physical strength, which use moderate or little intellectual faculties. It is thus, that, in the works of agriculture, young children are employed at watching over those domestic animals which are the most gentle and easiest to handle. In the workshops
they are employed at operations which fatigue little and which are capable of being accomplished with very little skill.

There is no doubt a great advantage in moulding the children to the work, from their very youngest age. But let us watch out for the cruel excess into which many foremen and manufacturing heads have fallen in Great Britain. These industrial managers oblige the young apprentices to work during a number of hours which is so considerable that the intervention of legislation has been necessary to reform the tasks required of the child, to less excessive limits, and which, however, they still alarm us when we consider the overwhelming fatigue that such a task can cause during use.

In some manufacturing establishments, directed by chiefs who unite the love of humanity to the elevation of thought, part of the time which may be legally required of young apprentices, is reserved for them to acquire those knowledges which are indispensable to any man who wishes to distinguish himself in the works of industry. These manufacturers have their young apprentices taught reading, writing and mathematics. They will soon join to these applications of geometry and of mechanics, such as we are teaching in our own courses...If they do not join with others in this last teaching, the young people, after having received the knowledge of writing and mathematics can, as soon as they become men, follow the free courses of these two sciences which soon will be established in all industrial cities of France.

The heads of establishments of industry have up to this time, given very little consideration to the influence of food on the workers,...
When we compare the manner in which French workers and English workers are fed we are struck with the extreme difference that the two ways of life present. In many professions, French workers eat no animal substances during the week; if they eat any on Sundays, it is only as an object of luxury. The English worker, on the contrary, makes a habitual use of animal foods of the most substantial sort.

It would be of great importance to influence the French worker to nourish himself in a more substantial manner. Today in a great many professions, the worker eats insufficient food to repair the daily loss of his strength. He arrives at the end of the week in a state of exhaustion. Each Sunday he tries to regain his lost force, by a food and by a drink which differs entirely both in nature and in quantity from the nourishment that he has taken during the working days. The same thing happens to him as we see happen to men who have gone hungry over a long period and who suddenly satisfy their appetite. They undergo an extreme unpleasantness, while they hoped to feel a new well-being; and Monday finds them more incapable of working than Sunday.

Such is the first reason for which it is necessary it seems to me, to which we can attribute the unfortunate custom that the greater part of the workers of the large cities have of not working on Monday.

The best means of remedying this inconvenience would be to influence little by little the artisans by wise counsel and by a good example which would be put beneath their eyes, which would take habitually a better type of nourishment. If they only employed in
nourishing themselves better during the six working days, the price of
the work of that day, which would not augment at all their expenses,
they would find themselves because of this fact, with a capability of
producing, during the five other days, a much greater quantity of
work, and consequently of requiring of their bosses proportional
salaries. They would avoid frequent illnesses and early decrepitude,
which are the inseparable companions of a life which is little regu-
lated. They would prolong a great deal the number of years during
which they could usefully dispense a great quantity of muscular strength.
They would diminish consequently, the number of years which become for
them years of misery, if they don't have the prudence to set aside,
during their youth and during their maturity the means to satisfy the
needs that always go with old age.

In regards to this, it is of great importance that the heads of
establishments of industry encourage, in any way in their power, a
type of community chest where the workers would place each day a portion
of their wage, to underwrite their needs in case of illness and when
there would be a lay-off from work and when age rendered them incapable
of working.

It is something to see at present, what an immense advantage the
masters of manufacturing places have in taking all possible means to
obtain from their workers a greater quantity of work in a given time.
A number of industrial enterprises which are impossible today will
become advantageously possible as soon as the work done in a day by
the worker is increased without decreasing in any way the pay of the
worker; the enterprises which are already lucrative will become even more so by the same change. The advantage is not always great for the worker. It is very important then that both the class of managers and the class of workers be made to understand this common advantage to them both which can produce such great changes in their well-being and their fortunes.

Aside from these first means of augmenting the product of his labor, the worker possesses others which he owes to the instruments which he makes use of, as well as to the intelligence with which he handles them. Tools designed for the same type of operation, with a more or less suitable form, and of a more or less good material, can give extremely different results. A worker, for example, with files of one form and perfect tempering, will be able to do double the work of a worker who does not have tools which are as good. The same must be said for most scissors, gimlets, drills, saws, etc.

In England, the importance of possessing tools which permit the performance of a great quantity of work during each working day is justly appreciated. In many industrial professions little advanced, a simple English worker possesses in tools, a value of from 1,000 to 1,200 francs; whereas a French worker of the same profession possesses hardly a quantity of tools which represents the value of 100 francs.

The increase of work, which results from better tools, also produces good results for the foreman and the manufacturer: ... Thus the foreman and manufacturer have no less interest than simple laborers,
in that these latter possess the best tools and also has large quantity of each type as the work may necessitate.

When the workers and their chiefs are fully convinced of the truth we are exposing at present, the former will wish to buy only the most excellent instruments, in every type; rules, squares, compasses of a mathematical exactitude; dials, scissors, drills, screws, etc., of as fine a material as industry is able to make. As workers and manufacturing heads become more demanding in this respect, our manufacturers of instruments of all types will be obliged to bring more care to their fabrications, as well as to the choice and the preparation of raw materials; the most advantageous results will arise from such a change.

When the tools have all the desirable qualities, when the worker employs the means of good nourishment and of good conduct, which are capable of increasing his physical strength, there will still remain for him means of increasing even more his work by a skillful use of his tools, in acquiring more and more skill in handling them. This skill is due in large part to intelligence of the worker, and to the attention which he brings to his work. When a worker is habitually distracted, when he shows little interest in the operations which are assigned to him, it is difficult for him to ever obtain a high degree of perfection and speed.

Everything being equal, workers who tend to their work with meditation and silence are preferred to those who work while making conversation, while playing, or distracting themselves in a thousand
different ways. Under this point of view, the French worker has a great deal to acquire before arriving at the degree of attention and of silence which characterizes the English worker.

After having examined what can influence the absolute quantity of work, it is necessary to examine in what way work can gain or lose by a more or less increased speed transmitted to the movements of the worker.

Let us take for example, the transportation of a load by two types of portor, such as we presented in the preceding lesson...

In all types of work that men do with their body and parts of their body, there is a certain proportion of strength and speed which gives the greatest useful effect, that is to say, which causes him to overcome a determined resistance, such as the product of the resistance times space is a maximum.

It is to the attentive worker, and above all the foreman and the manufacturer to force himself in all cases, to appreciate the speed in this effect which, when well combined, should produce the greatest useful effect thus measured.

When the spirit of men in industry shall have turned toward this type of observation, it is impossible to doubt that, in a great number of works of the art, there will be established between effort and speed, new proportions which are a great deal more advantageous than the proportion furnished by routine.

A very skillful manufacturer of machines in England, Mr. Galloway, told me several times that one of the most remarkable improvements in
metal working and one which has brought the greatest economy to the cost of labor, for the boring of cast iron, is to considerably decrease the speed of the drilling,...It is of great importance that we study with care for each type of industry, the different degrees of speed which are most fitting to each mechanical operation. These precise results of practice...should be published in a compilation.

...[An example] shows that in the manufacturing establishments where there is a great amount of capital in relation to the outlay for labor, it is very important to employ all means possible for the acceleration of work,...

As the industry of people advances, as the leaders become greater in number, the value of material in industrial establishments becomes also more considerable in relation to the labor cost. Consequently it is of greater importance that the speed of fabrication be accelerated.

Thus, it should be regarded as a mathematical principle already proven that the more an industry is perfected, the greater speed the industrial operations should acquire; in order to obtain at all times, the greatest useful effect.

...When a man possesses a considerable amount of capital and makes the most of it by his intelligence, time becomes for this man the object of very great importance...Men must then, make larger and larger sacrifices to economize their time and give greater speed to all their
operations proportionately as they acquire greater capital...

... Proportionately as the movement assigned to each worker becomes simpler and less different from one another, repetition of these movements becomes easier, more rapid and more perfect. From this we have the surprising results of the division of labor.

[Dupin gave a detailed discussion of pin-making and how its various operations are affected by the division of labor.]

A man, as we have said, who is not used to the repetition of these elementary movements and who would be charged with the fabrication of one after the other of complete pins would not make twenty in a day. In a day he could not execute more than 7,560 useful movements. He would lose almost 4/5 of his time: first, because his movements would be slower; second, because in passing continually, from one type of movement to another type, he would never develop any rhythm or momentum; third, finally because it would be necessary for him to put down too often certain tools, to look for and to pick up others and to put down the same ones several minutes later.

It is a precious art in foremen and manufacturers to know how to break a job into its simplest elements, and nevertheless to keep them as small a number as possible, to assign each part to separate workers. This advantage may be pushed much further in large establishments than in small ones, because there are more workers to be separated into distinct working rooms. When such a division of work is put into operation the most scrupulous attention must be exercised to calculate
the duration of each type of work operation, in order to proportion
them to the particular number of workers that are assigned to it.
In this way no one remains idle, and the total establishment attains
the maximum rapidity.

The division of work has the advantage of presenting a number of
simple operations so regular that mechanics can produce them with the
greatest facility.

Thus an example which I have just cited, one can employ: mill-
stones for the purposes of sharpening by handfuls the pins made in
the factory; turnstiles for beading at one time a great number of the
ferrules which form heads of the pin; scissors which with a single
stroke trim many metallic threads to the length best suited to making
the body of the pins...On the contrary it would be very costly and very
difficult to make one single machine which...would make complete pins
by diverse and complicated movements.

The division of labor then has the double advantage of making the
function of a man more rapid and easier as well as more efficient, and
the combination of these with the work of machines.

... I am able to conclude, by relying on positive facts, that in spite
of the division of labor and in spite of the purely mechanical industry
to which we have descended, through improvement, the fabrication of
several arts, by the total progress of these arts, and above all
through the results of mechanics, the proportion of workers who need
a well-developed intelligence to carry out their profession is today
in a greater and more advantageous relationship than it was among those people where industry remained in infancy.

... You should see now how many imposing sources exist by which we may obtain a great result from human strength in the works of industry; by making use of better tools, better instruments, better machines; by giving to the operations a speed proportionate to the worth of materials, importance, and urgency of commercial needs; by adding all the resources of knowledge and of attention to use the fundamental ideas which will be furnished by observation.

It is very important to examine the apprenticeship of men devoted to industry; apprenticeship which is not only a relationship to movements of the parts of the body, but in relationship to the improvement of the senses, as we have indicated in the two first lessons, and in the relationship for improving the intelligence of reading, writing, mathematics, geometry and mechanics applied to the arts.

When we combine all these means to give the strength of man the greatest effect that it can produce it will be surprising to see what more varied, more perfect, and more numerous results shall be obtained with a given population. Proportionately as we increase the means of instruction, on the scale of observation in those men devoted to industry, the improving of detail, which produces at length the great results of the whole, will be multiplied in all types of work; inventions will become more numerous and among these there will be presented
necessarily some very important ones. Thus industry will advance with a more and more rapid step.

... It is very important to employ women at work where their intelligence has more reason to be exercised than their physical strength. Women are more gifted with a spirit of observation, full of finesse; they are capable of prolonged attention, provided they do not necessitate too profound a combination of spiritual attention too strong at each moment.

It is evident that the progress of industry should multiply the occupations suitable for the feminine sex. The women incapable of executing important works of strength, can watch over the operations of a powerful machine; she can stop or start this machine, by the movement of a simple lever or a light cord and do it with as much efficiency as the most robust man.

It is up to the foreman and manufacturers to divide their work in such a manner that persons of the feminine sex may find advantageous employment. They will be able, by this means, to pay cheaper wages than for the work of men and nevertheless give to working families a total salary of more considerable size.
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- No. 13,342 Friday, July 27, 1827
- No. 13,376 Wednesday, September 5, 1827
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- No. 14,937 Wednesday, August 22, 1832
- No. 15,010 Thursday, November 15, 1832
- No. 15,011 Friday, November 16, 1832
- No. 15,017 Friday, November 23, 1832
- No. 15,021 Wednesday, November 28, 1832
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I, John Hardie Hoagland, was born in Woodhaven, New York, December 22, 1919. I received my secondary school education in the public schools of Upper Arlington, Ohio and Washington, D.C. My undergraduate education was at Oberlin College, from which I received my Bachelor of Arts in 1941. While working as a time study engineer at Frigidaire Division of General Motors, 1941-42, I began my engineering education at the University of Dayton. This was followed by further engineering studies at Ohio State University until called to active duty in the United States Naval Reserves in 1943. Three years with the United States Navy were spent studying electronics at Harvard University and Massachusetts Institute of Technology, followed by overseas service in the Pacific theatre of operations. In 1946-47 I attended Harvard Graduate School of Business Administration, from which I received my M. B. A. in 1947. Following work as a production and engineering cost analyst with Hobart Manufacturing Company and foreman with Sylvania Electric Products Company, I enrolled in Ohio State University to complete the requirements for the Doctor of Philosophy degree. Meanwhile, I served three years as instructor at Ohio State University. Since 1952 I have served as an assistant professor at Michigan State College.