1968/1

CIBA REVIEW

The evolution of mills and factories

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Cover and feature

Old East India Wharf at London Bridge in about 1750. Painting by Samuel Scott (c. 1710–1772), photo by Art-Wood Photography Ltd., London. Crown Copyright. By courtesy of Victoria & Albert Museum, London.

In the 17th and early 18th century London was the centre of the trade in gaily coloured cottons which, imported from India, had become the great fashion in England and on the Continent. While writers such as Daniel Defoe feared that the "Indian Stuffs" would ruin Britain's economy, new machines were in the making and the factory system was being born. Soon Britain's mills were churning out textiles which flooded the world's markets, and the First Industrial Revolution was in full swing. Mechanization and mills rapidly spread through Europe, remoulding whole economies and technologies and turning peasants into factory hands, while feudal and guild based societies crumbled as they sought to adapt to a dynamic new age.

The first Industrial Revolution was followed by the Second, and a Third has begun with the advent of nuclear power and automation. But industrial economies began with the textile mills and the steam engine—they were the foundations of our modern world.

Next issue: 1968/2, "Fibres and fabrics of biblical times"

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Origins of the factory system

"Industrial Revolution"?

The factory system is generally agreed to have had its origins in the cotton mills of late 18th century England. Its widespread adoption changed the world, and the period in which it revolutionized manufacturing methods is known as the "Industrial Revolution". Although used in 1788 by Arthur Young with reference to the cotton industry, the word "revolution" is today considered by many scholars to have been poorly chosen. The advent of factories, they argue, was no sudden occurrence but the outcome of developments which, beginning in preceding centuries and coming to a head in about 1700, were subsequently accelerated and gathered ever greater momentum.

Many theories have been advanced to explain just why it should have been the late 18th century British textile industry which gave birth to mass production methods, but economists and historians all agree that it is extremely difficult, in fact impossible, to provide a completely satisfactory explanation for such sweeping changes. On the other hand, it is rather strange that little attempt has been made to give reasons why factories were not already in existence everywhere before the 18th century, especially in view of the enormous economic advantages with which mass production methods are credited. Certainly there was no dearth of primitive and early prototypes, and large manufactories existed hundreds of years before Richard Arkwright built his first spinning frame and mill. But—were those early workshops really factories in the modern sense of the word?

What is a factory?

A definition

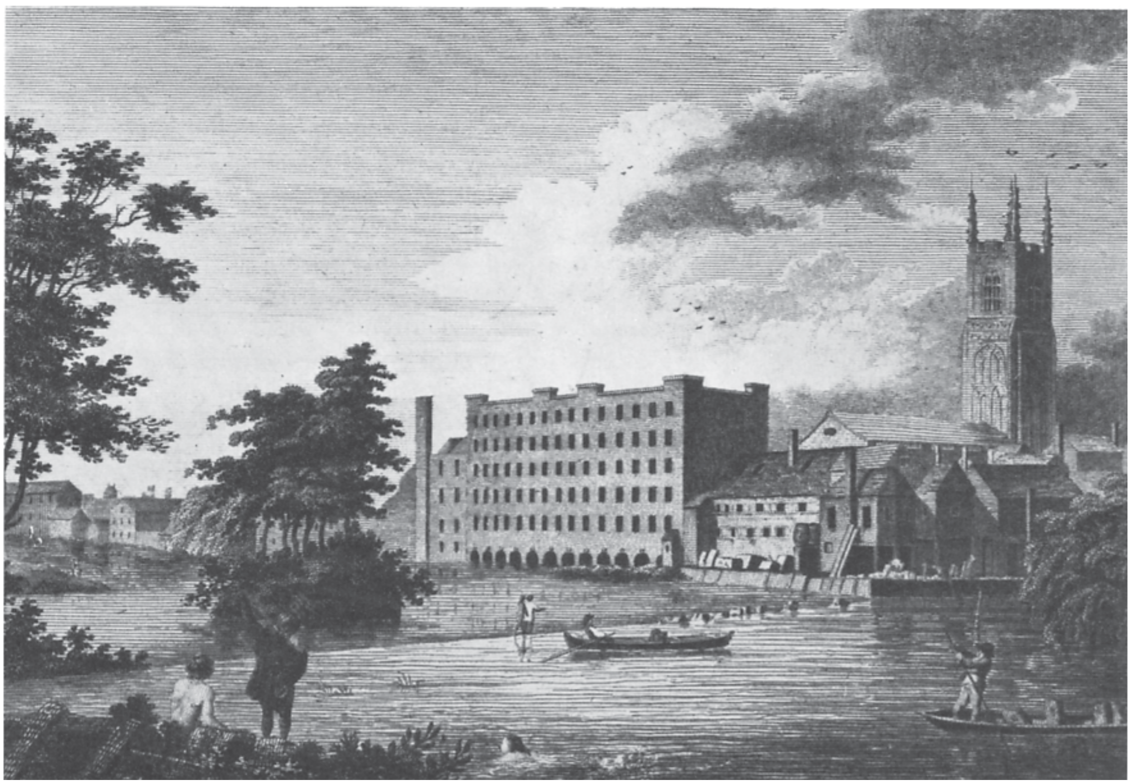
A factory is characterized primarily by the use of machines, the utilization of mechanical forces to set them in motion, and the employment of operatives on division of labour principles, all on a single, permanent site. These characteristics are listed, in addition to others of a more politico-social nature, in the definitions given in the factory laws that have been enacted in most civilized countries.

"The factory system is the inevitable corollary of mechanization. A collection of tools consisting of interconnected parts activated by a central source of power can be set up only on a single site where their functioning is controlled by disciplined personnel. This site is a factory; there is no other definition", says French economic historian Paul Mantoux.

Machines, mechanical power and division of labour, the basic units of organized manufacturing processes, were by no means unknown prior to the 18th century. Simple machines such as hand-mills, potters' wheels, lathes and looms were used in prehistoric times, and the Romans built water-powered grain-mills. In the Middle Ages, large numbers of mechanical devices were employed by craftsmen and builders, very extensive use being made of water-power in late medieval days. For the early capitalistic period, Werner Sombart lists no less than 18 different types of mill alone, among which powder-mills, paper-mills, dyewood chipping-mills, oil-mills, and ribbon-looms predominated.

Max Weber, the famous German sociologist and economist, regarded neither machines nor the use of mechanical power as being the essential attributes of a factory. Similarly, he

1. The first silk throwing mill in Britain was built in about 1717 on the banks of the Derwent at Derby by Sir Thomas Lombe (1685–1739). The design of the water-powered throwsters was based on the old Lucchese model, but the first costs and size of the mill greatly impressed Lombe's contemporaries.
Etching of a drawing by J. Nixon, by courtesy of the Central Library, Wardwick/Derby.



2. Late 18th century bleach mill in Northern Ireland. The water-powered machinery consisted of a beetling engine (right rear), a fulling engine (centre), and a rope washing machine. Bowking and boiling, wringing-out, and smoothing were still manual operations. Mezzotint by William Hinks, London, 1791.

3. London draper's shop, c. 1800. Contemporary drawing from "The Repository"; photo: J. Gérard, Paris. Adoption of the factory system resulted in the mass production of cheap consumer goods and, because old-style shops provided inadequate sales outlets, the advent of department stores.

saw neither the division nor the coordination of labour as distinguishing characteristics, since these were perfected in the royal and temple manufactories of ancient Egypt and Greece. Weber stressed that the factory system did not originate in craftmen's workshops, but that it grew up and evolved adjacent to them. Neither did it originate in the cottage industry which, as is so often done, cannot be regarded as a capitalistic early form or "decentralized factory". On the contrary, said Weber, a factory "is a capitalistically organized production process employing specialized and coordinated working methods within a workshop and utilizing invested capital".

Craftsmen were herded together to achieve continuous centralized production in very early times, but there was no thorough rationalization of manufacturing methods in such "workshops" and it was possible to divide up work at will. Hence, argued Weber, we can regard as a factory neither a prehistoric site where weapons, religious graffiti, pottery or ornaments were turned out in large quantities, nor an Egyptian temple workshop or a Greek or Roman "ergasterion", and not even one of the large manufactories which were set up from the Middle Ages onwards.

This is Professor Weber's careful analysis of a factory's characteristics. If we accept and use his definition, we shall eliminate the risk of designating with a single term both modern factories and other, economically very different industrial units.

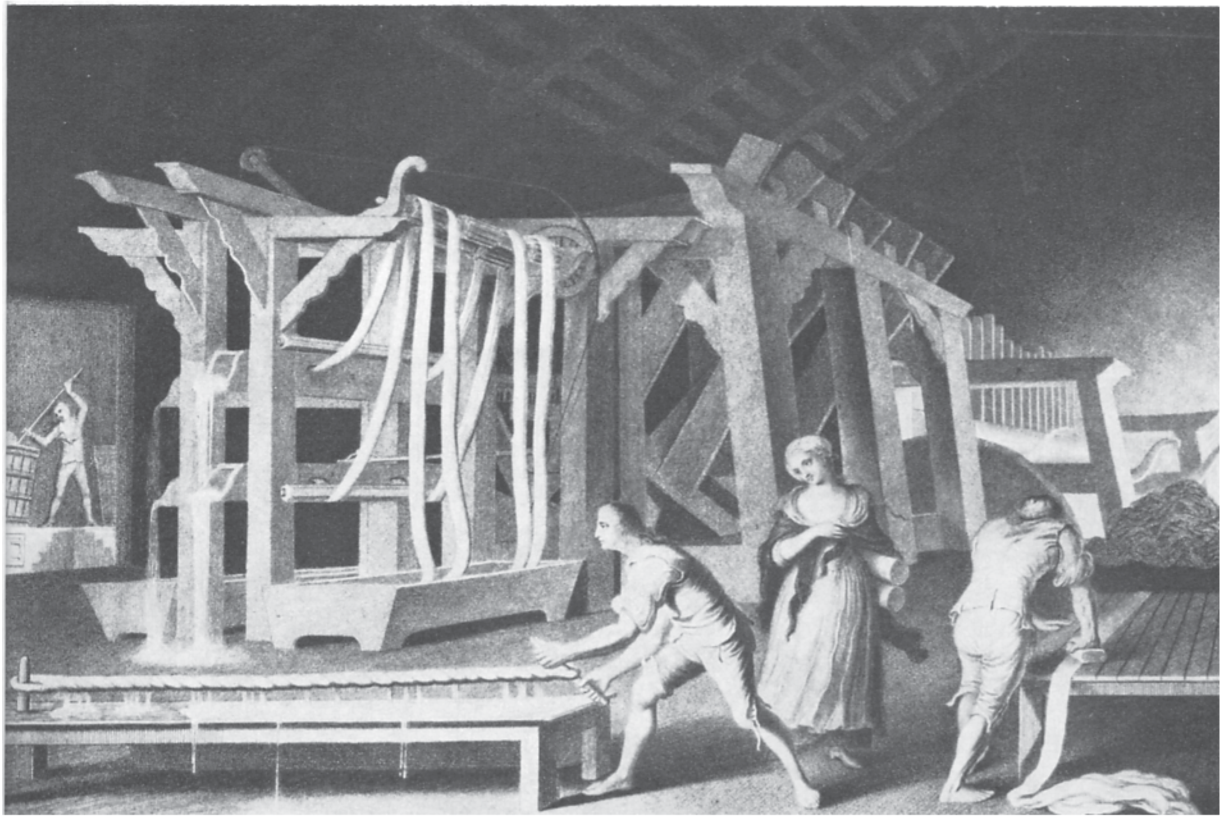
Colloquialisms

In the past, the word now used to designate an industrial plant often meant something very different. In English, a "mill" was once nothing but a building fitted with machinery for grinding corn and a "factory" was a merchant company's foreign trading station. In German, "fabrikant" (manufacturer) originally meant a craftsman and was used particularly of smiths (Latin "faber") and carpenters; "fabrik" (factory) was the medieval word for the group of builders who worked on cathedrals. In both Germany and Switzerland, no attempt was long made to distinguish between manufactories and factories or even between cottage industries and factories. Thus Zürich's "factory regulations" (Obrigkeitlich errichtete *Fabrik*ordnung) of 1787 were concerned primarily with governing the rates of pay for cottage industry operatives. The official census of 1787, the "Etat der Baumwoll-*Fabriken* im Kanton Zürich", listed 34,075 hand spinning machines in addition to 2,087 calico and 4,392 muslin looms, yet in that year not a single cotton mill was in operation anywhere in Switzerland.

Textile industry leads the way

The early history of factories was dominated by the technological advances made by the textile industry. Other industries also set up factories at an early date, but these never developed beyond a comparatively modest stage and certainly never spread and multiplied as rapidly as the first textile mills. Consequently, their advent also resulted in less extensive social regrouping of the working classes.

No comprehensive statistical data are available on the factory-like workshops in existence in England before 1760, i.e. prior to the advent of cotton mills. The detailed information provided by Diderot and d'Alembert's great



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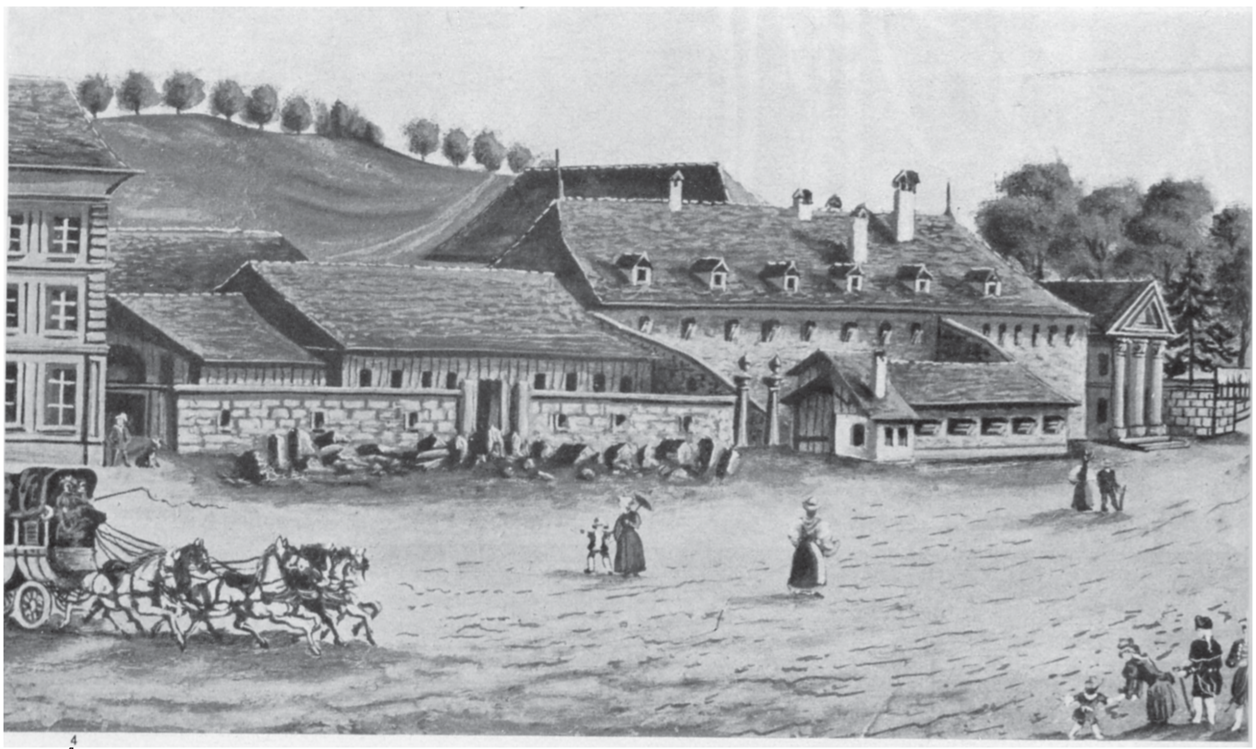
4. The "Schallenhaus" in Bern (c. 1780), where convicts were kept busy combing, spinning, and weaving wool. In the age of Mercantilism, the authorities sought to further industry by providing manufacturers with the cheap labour of prisoners and poor-house inmates. Contemporary drawing. By courtesy of Museum of History, Bern.



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French encyclopedia of 1750 is therefore invaluable; it gives a complete picture of the technology of that age and all the trades with their special tools, gear and machines are depicted in hundreds of copper-plate etchings in the 16 folio-volumes of its "planches". The most important among the highly developed industries with pronounced factory-like characteristics were the silk, linen, wool, cotton, hosiery and lace industries, followed by the ropemaking and papermaking industries.

Advanced technology

The French encyclopedia gives special place to the textile industry, not only because of its involved working methods but because of its time-honoured, highly developed techniques. In no other industry had the mass production of goods comparable to yarns and fabrics begun so early and nowhere had they retained such an extraordinary diversity of form. In preceding centuries, spinners' and weavers' techniques had produced outstanding fabrics

5. In the 18th century, abandoned Waltham Abbey in Essex was converted into what became a flourishing print works. Such works blazed the way to a new industrial unit in which craftsmen plied their different trades together under one roof.
Etching by Ch. Barber of a drawing by W. H. Bartelett (1809–1854).

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such as the unexcelled diaphanous linen of ancient Egypt, Indian muslins, Chinese silks, medieval Italian brocades, and the fine cloths of Flanders.

These techniques soon prompted a demand for labour saving devices. For even the warp threads in a hand-loom represented a large quantity of yarn which had first to be prepared, after it came off the spindle, by a no means simple series of operations including winding, twisting, warping, bleaching, dyeing, and finishing. A Florentine silk-loom carried up to 35,000 warp yarns, and complicated operations went into the spinning of the gold thread used in figured fabrics.

Silk mills

It is thus apparent why the textile industry played a leading role in evolving the factory system. In the sequence of developments involved, it was a characteristic feature that manufactory sub-sections engaged in opera-

tions forming part of a process were the first production units to become what we have chosen to define as factories. These were closely associated with numerous widely dispersed workshops or a cottage industry, forming the cores of larger units which were in turn frequently the economic hearts of whole enterprises.
The earliest factory-type sub-manufactories of this kind were the silk mills. Silk throwing machines originated in Lucca, where harsh penalties were imposed in vain endeavours to keep secret the details of their design. From the 13th century onwards, they were copied all over northern Italy and then in France, Switzerland, Holland, Germany, Austria and England. In Zürich, refugees from Locarno built the first silk mills in about 1568 (CIBA Review No. 80, "Lucchese silks").

Although the silk mills of Upper Italy had been driven by water-wheels since the 13th century, most of those first erected in Switzerland were powered by human muscles. But not for long: a large Swiss water-wheel mill with 7,000 spindles was built in 1591.

Silk mills developed fastest in England. After resorting to industrial espionage in Italy and obtaining a government subsidy, Thomas Lombe of Derby in about 1717 built and worked a 19,000-spindle throwing mill, the first in England, on the banks of the Derwent. All told, seven such large mills were built before the advent of the first cotton mills in the 1760s. Contemporary descriptions indicate that these much admired structures were really very respectable industrial plants. For instance, that at Derby had 420 windows and that at Stockport 380. All hired hundreds of hands, that at Derby employing 300 operatives, most of them women and children.
The first costs of these throwing mills were heavy. Those of Lombe's mill at Derby totalled £ 30,000 and those for the Stockport installation £ 10,000, while large sums were tied up in the supplies of raw silk. Without a doubt, the mills were capitalistic enterprises and factories in the modern sense. And it was hardly a coincidence that they were spawned by the silk industry with its heavy capital investments by dealers in expensive raw materials.

The wool industry

Other factory-type sub-manufactories appeared at an early date in the wool industry, which also processes expensive raw materials. These were the water-powered fulling mills whose construction necessitated extensive investments. They were first built in England and France, but proved to be so economical in operation that not even strict guild laws were able to prevent their being copied elsewhere.
Dye-houses and bleach works also used heavy equipment such as fulling engines and expression rollers which, like carding engines and warping frames, often became the nucleus of an industrial plant. Not every processing operation in the early textile industry could be carried out by craftsmen working in scattered workshops or at home. Whenever operations called for particularly painstaking workmanship, entrepreneurs preferred to have them carried out under their personal supervision.

Factors prompting industrialization

Poor houses and spinning schools
Poor houses or spinning schools were the nuclei of some of the first mills. In the 17th and 18th centuries, the authorities everywhere had considerable difficulty in finding work for the great numbers of vagrants, destitute persons and orphans then roaming the countryside. Many entrepreneurs astutely took advantage of the situation and exploited this cheap labour by setting up large poor-house workshops in former monasteries and abandoned chateaux. Additional advantages accrued to them because official permission to manufacture fabrics on this basis and scale was commonly granted together with certain privileges, such as exemption from taxation, rights to land and water, and subsidies which helped in overcoming initial difficulties. Thus a whole series of poor-house workshops and spinning schools came into being in France, Austria, Germany and Switzerland, some of them even using machines. In the U.S.A., the first textile factories also had their origins in such semi-social welfare enterprises.

Theories

The arguments advanced by sociologists and historians of the old school to account for the origin and spread of the factory system in the textile industry have proved to be invalid. This is particularly true of the widely propagated theory based on the difference in output capacity between spinning and weaving mills. The introduction of John Kay's "fly" shuttle in 1733 doubled the output of fabric, it was argued, thus increasing by 100% the demand for yarn and prompting the invention of the spinning frame. Gustav Schmoller even went so far as to state that Hargreave's, Arkwright's and Robert's spinning frames would never have been devised and perfected had the fly shuttle not been invented, and that mechanical spinning mills could never have been made to work without James Watt's steam engine. Today, we know that Arkwright's and the other inventors' spinning frames were in use long before Kay's fly shuttle was introduced.

John Kay's "fly" shuttle
Kay's invention was based on three innovations: he put wheels on the shuttle, inserted a pirn, and drove it to and fro with pickers (drivers) threaded on spindles in shuttle boxes on each side of the warp space and actuated by fly cords alternately yanked taut with a small handle ("fly pin").
Pirns had previously been in use in the silk industry for hundreds of years (the English credited the Dutch with their invention), and weavers testified in court that shuttles with wheels had been known before Kay's time. Yet it was these two innovations that caught on fastest; the picking mechanism was too weak and badly needed improving. In Eng-

Early mill machinery was devised and developed thanks to the inventive genius of practical men, small entrepreneurs and craftsmen who rarely won the recognition they deserved.
6. John Kay (1704–1780/81), the inventor of the flying shuttle, had endless financial difficulties with his invention and the opposition of weavers to its use.

7. Sir John Bessemer (1813–1898) was an inventor with a scientific background. Famous for his steel making process, he registered 117 patents, one dated 1851 being for a vacuum-printing process for fabrics.

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land, the flying shuttle fell more and more into disuse after Kay emigrated to France in 1747. The French government realized the potential value of his invention but endeavours to compel its widespread adoption were a total failure. In Germany, the flying shuttle did not come into more general use until after 1820.

Steam engines

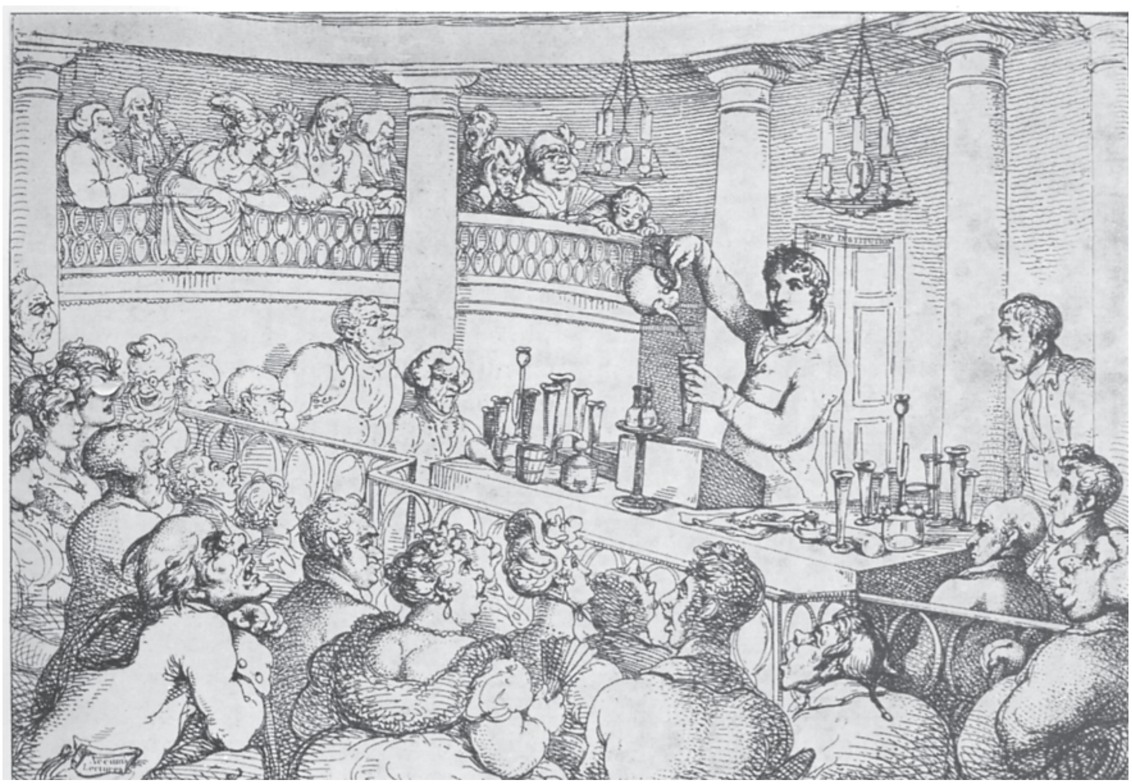
Another theory traces the advent of the factory system to the invention of the steam engine, claiming that this ended dependence on water-power and made it possible to build mills almost anywhere. Again, we know now that this argument does not tally with the facts.

In England's cotton spinning mills, steam power was first introduced by Peel in 1787, and then by Drinkwater in 1789 and Arkwright in 1790. By about 1800, 289 steam engines with a total output of 4,543 h.p. were in use. Of these, 32 were in Manchester, 11 in Birmingham, and 20 in Leeds. About half of Britain's cotton spinning mills were still using water-power in 1833, although by this time the coal seams under the foundations of many were already being mined.

In Switzerland, only 14 of Zürich's 106 cotton spinning mills had installed steam engines by 1827. In Austro-Hungary and Saxony, the cotton industry was equally tardy in switching over to steam power. In France, windmills still supplied the power used by seven cotton spinning mills in 1856.

Animal muscle was used to keep machines turning until a remarkably late date. For instance, in 1819 a St. Gallen mill was relying on an ox in a treadmill to keep its spinning

8. A public lecture of the type given in Britain from 1800 onwards in an endeavour to provide the public with a grounding in physics. The cartoonist, Th. Rowlandson (1756–1822), was ridiculing people who attended such lectures only to kill time or because it was "the thing to do", stressing the difference between them and the lecturer, the representative of the progressive younger generation.



frames moving, and at an Arbon mill a horse-gin was still the only source of power in 1864. Even more remarkable was a tendency to continue using human muscle. Thus most of the 60 silk throwing mills in and around Zürich long relied on gins kept turning by girls, the so-called "radmeitschi", while in the 1890s one silk winding shop in the city still employed a man to hand-crank the flywheel which powered its frames.

The East India Trade

One important factor prompting industrialization of cotton manufacture was correctly identified, probably for the first time, in "Considerations on the East India Trade" (1701). The unknown author pointed out that less and cheaper labour was required to import goods from the East Indies than to make them in England. This, he reasoned, was probably the incentive prompting the invention of "arts and mills and engines" which would cut industrial manpower costs generally and eventually lower the price of industrial products without reducing wages.

The volume of cotton goods pouring into Europe from India had become a veritable flood during the 16th century. In 1708 Daniel Defoe wrote (A Review of the State of the British Nation, Vol. IV, No. 152):

"... we saw our Persons of Quality dress'd in *Indian* Carpets, which but a few Years before their Chamber-Maids would have thought too ordinary for them; the Chints were advanc'd from lying on their Floors to their Backs, from the Foot-Cloth to the Petticoat, and even the QUEEN Herself at that Time was pleased to appear in China and Japan, I mean China Silks and Callico.

"Nor was this all, but it crept into our Houses, our Closets, and Bed-Chambers, Curtains, Cushions, Chairs, and at last Beds themselves were nothing but Callicoes or Indian Stuffs, and in short almost every Thing that used to be made of Wool or Silk, relating either to the Dress of the Women, or the Furniture of our Houses, was supply'd by the Indian Trade.

"What remain'd then for our People to do, but to stand still and look on, see the Bread taken out of their Mouths, and the *East-India* Trade carry away the whole Employment of their People?"

But instead of standing still and looking on, the British invented the factory system. Soon the flow of cheap cottons was reversed and before long it was English fabrics that were depriving Indian weavers of their livelihood. Then, in recent decades, the flow of goods again switched from East to West; the factory system had been adopted in the Far East...

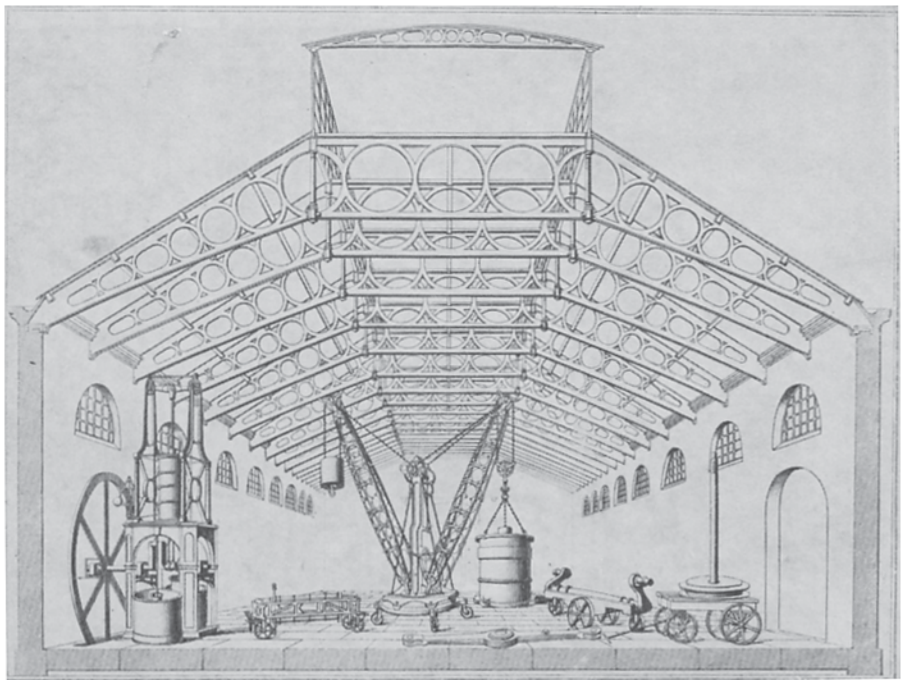
Division of labour and inventive genius

The general tendency to assemble operatives and implements in large manufactories apparent in early 18th century England was a further factor favouring industrialization. Chapman even argues that with or without revolutionary inventions, this trend alone would have assured the rise of the factory system.

At that time, various phases in the preparatory work involved in weaving became separate operations. There appeared workshops specializing in warp beaming, carding and, in particular, in doubling and twisting, division of labour becoming more and more pronounced and widespread. This prompted the invention of so many textile machines by Englishmen who, according to their own sociologists and historians, do not in general seem to have had any special mechanical gifts. And it is a fact that John Kay and Lewis Paul were of French extraction, that throwing mills originated in northern Italy, and that twisting and ribbon mills came from Holland. Nevertheless, it was in England that the transition to the factory system was first made. Victor S. Clark sees the reason for this phenomenon in the fact that machines perform clearly defined operations, i.e. they correspond to the logical steps that go to make up a whole manufacturing process and their invention is prompted by the extent to which work was organized before they appeared. Great inventions were made in England because each industry had developed clearly distinguishable production phases and work had undergone specialization. Efficient workshop routine had broken down processes into a number of basic operations which could each be carried out by a machine.

10. Late 18th century Indian calico, an ornately printed and painted cotton fabric of the type imported in great quantities by the East India Company before and after 1700. Efforts to produce comparable fabrics at competitive prices contributed to the mechanization of cotton manufacture and the evolution of the factory system in Britain.
By courtesy of Musée de l'Impression sur Etoffes, Mulhouse.

10a. Marine steam-engine assembly shop, Maudslay, Sons & Field, London, c. 1820. Manufacturers began to turn out standard-design units in large series when the rising demand for prime movers and machine tools could no longer be met by having craftsmen make them to order.
Etching by Bury from "L'Industrie, Exposition de 1874" by St. Flachat.
The iron girder structure of the assembly shop roof eventually became a typical feature of industrial buildings. The first iron-frame mill was erected at Shrewsbury in 1796 to spin linen.



Expensive raw materials

The steady increase in pilfering by cottage industry operatives of raw materials (then relatively more expensive than they are today) was another important factor which prompted the wealthier entrepreneurs to build factories. Pilfering had been the entrepreneur's bugbear everywhere for centuries; guild regulations starting with the 13th century French "Livre des métiers" abounded in measures devised to prevent it. In England, harsh punishments were imposed on home weavers convicted of theft, but had little effect. In fact, court records show that sometimes sentences provoked outbreaks of violence instead; cottage industry operatives apparently felt they were entitled to retain part of the raw and semi-finished materials in order to augment their low pay.

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The economic impact

Widespread adoption of the factory system had extensive economic effects. These are, however, difficult to assess in their entirety or to isolate from other economic factors influencing society at the time. Hence only the most important will be dealt with here.

Statistics and dire prophecies

The increased productivity of the British textile industry following mechanization was described very convincingly by Friedrich List in his "Die grosse Gewerberevolution" (1843).

According to List's statistics, in 1770 Britain's manufactories employed no more than two million operatives, five-sixths of all industrial products were consumed at home, only 300,000 operatives were producing for export and about half of their output went to the colonies. Then, installing more and more machines, British factories produced goods equivalent to the labour of 10 million operatives in 1792, of 200 million operatives in 1827, and of 1,000 million operatives in 1843. List commented: "Even if we assume only one-tenth is for export, (the equivalent of) 100 million workers or 700 times as many as in 1770 are competing with the manual labour of the importing countries . . . The Island Kingdom seems to have become a monster which, as it has already done in part, threatens to overwhelm the productive diligence of all other nations and to render impossible for ever their industrial growth."

List predicted that, eventually, Britain would manufacture apparel and tools for all the world while other countries had employment only for bakers, bricklayers, chimney-sweeps and the like. Made as the First Industrial Revolution was coming to a close in Britain, List's dire prophesy is interesting on two counts. It mirrors the general attitude toward the factory system a century ago, and it shows how even a man as brilliant as List could err in his estimate of potential industrial development in countries other than Britain.

Long-term effects

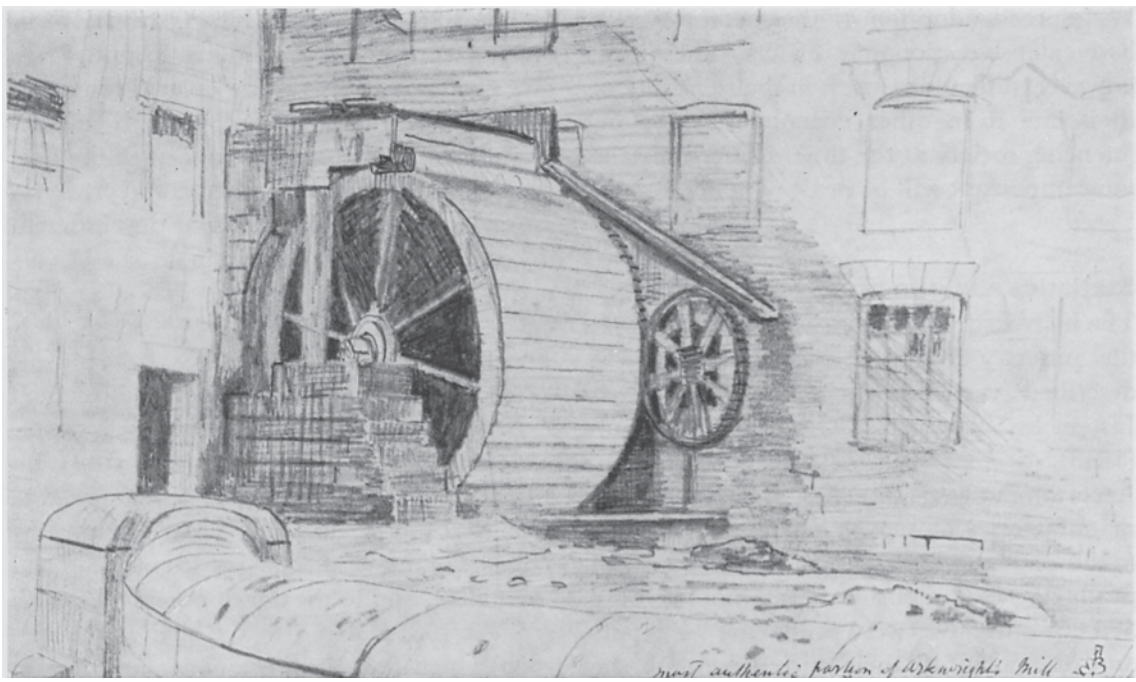
The introduction of the factory system in Britain had far-reaching long-term effects. It spawned a mechanical engineering industry which, by supplying machines to textile mills all over the world, led to the rapid spread of collieries and foundries in what became the "Black Country", to the growth of trade and commerce, and to the development of a modern transport system. It gave birth to the railways which increased passenger and freight traffic to previously undreamed of proportions, and prompted the rapid growth of cities and towns.

Mass production methods

But mass production was itself the most important outcome of mechanization. It increased not only the supply of material things but also the scope of the recreational and educational facilities available to the working man.

Mass production is based on high productivity, which can be achieved in a number of different ways. This difference in possible approach is the explanation for the varying degrees of success and economic effect achieved by individual technological innovations in the textile industry.

11. Water-wheel of a mill built by Richard Arkwright. Sketch made in 1878 by Ford Madox Brown (1821–1893) for frescos in Manchester Town Hall. By courtesy of Tate Gallery, London.
The steam engine took a long time to oust the water-wheel and even as late as 1833 about 50 % of all British cotton spinning mills were still using water-power.



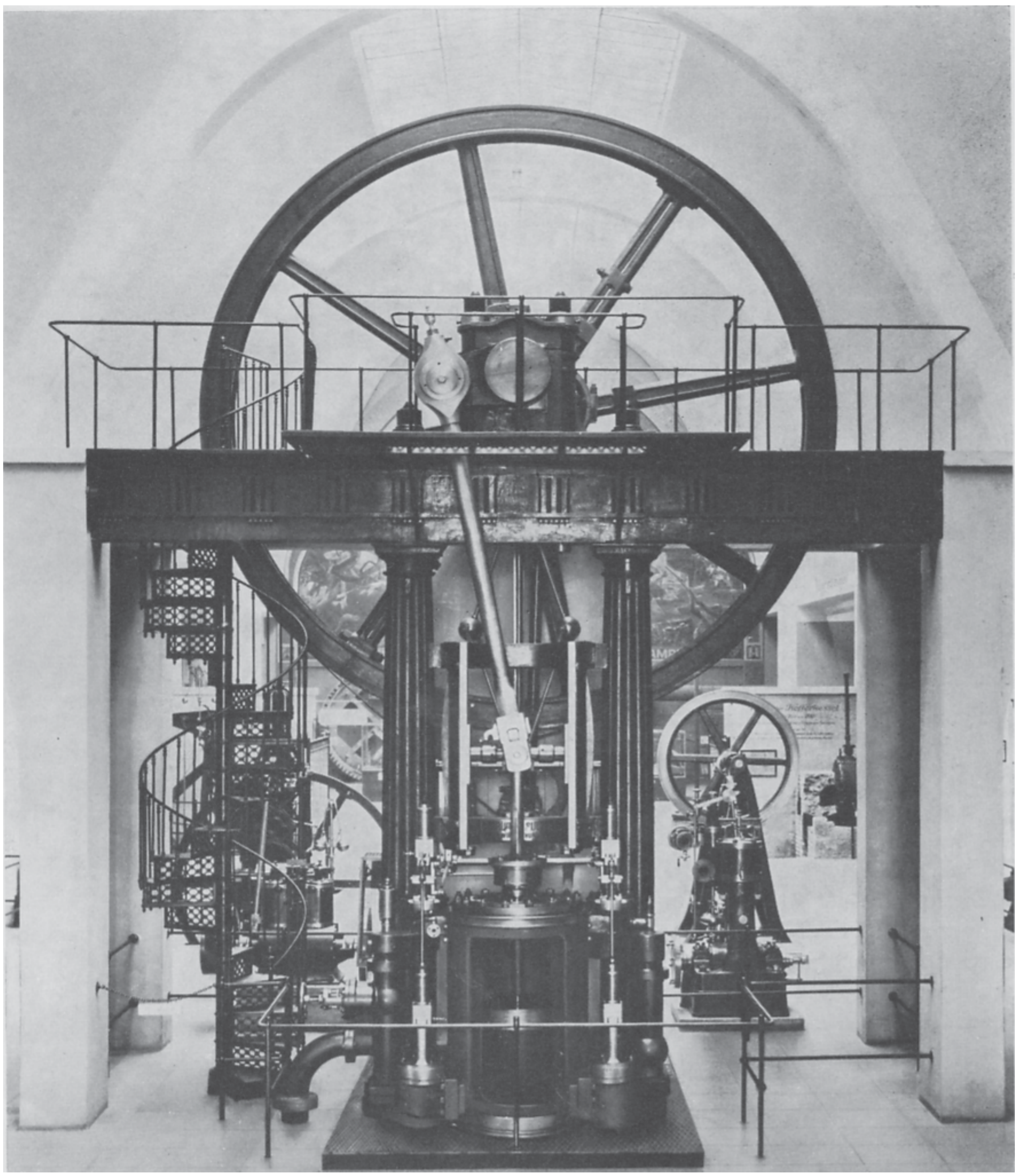
Continuous processes

Every manufacturing process can be thought of as a series of constantly repeated individual operations separated by intervals during which the material being processed is delivered, set in position and handed on, and in which the machines used are adjusted and checked for performance, etc. Shortening or eliminating the unproductive breaks would be one means of increasing productivity and would result in a continuous process. This goal can best be attained by resorting wherever possible to the cyclic flow or rotary principle. Occasionally, it is even possible to combine two previously separate operations. For instance, in the silk mills of Lucca yarns were given twist and wound onto reels in one operation.

Acceleration

Productivity can also be boosted by speeding up the key operation in a manufacturing process, e.g. by accelerating spindle speed in spinning. However, since friction increases not in direct proportion to the speed but in proportion to the square of the speed, power consumption goes up accordingly and sets limits to the degree of acceleration which is feasible. Nevertheless, working speeds have been increased enormously. For instance, Arkwright's flyer spindle turned at 3000–4000 r.p.m. but modern roller-bearing spindles whirl at up to 20,000 r.p.m. These speeds only became possible when the cumbersome flyers were eliminated from the thread guiding system after the invention of the cap spinning frame by

12. The first 160 h.p. valve regulated steam engine built by Gebr. Sulzer AG in 1865 for the Blumer & Biedermann cotton spinning mill at Bülach, Switzerland. The engine was in constant use until 1904. By courtesy of Deutsches Museum, Munich.



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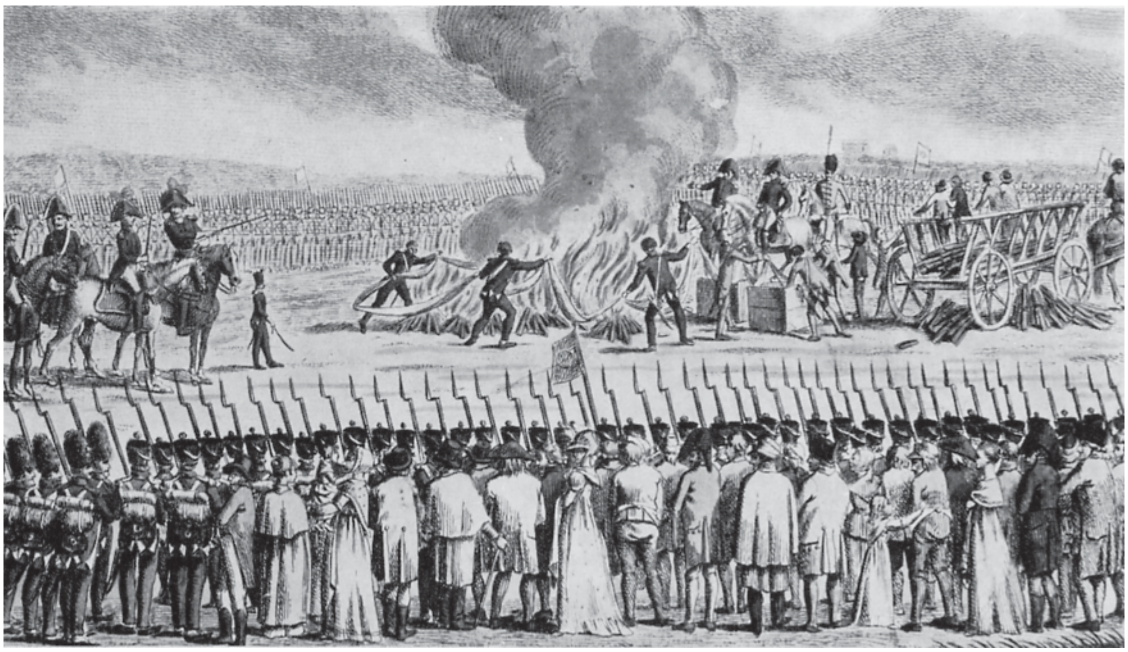
13. British goods being burned at Frankfurt am Main in 1810. Napoleon tried to disrupt Britain's economy by banning British goods from Continental markets. His "Continental System" furthered the growth of mainland industry and led to the founding of numerous new mills and factories.
Contemporary drawing. By courtesy of Historisches Museum, Frankfurt/Main.



Franz Girardoni at Unterwaltersdorf near Vienna in 1822. (Standard text-books erroneously state this invention was made in 1824 by an American named Danforth.)

Coordination

The most effective means of increasing productivity is to coordinate all manufacturing processes, individual operations then being carried out synchronously and automatically, and operatives doing no more than mind the machines. Such coordination is not always easy to achieve and, for instance, simultaneous spinning of two or more yarns was long an unattainable ideal. (Some of Leonardo da Vinci's famous sketches indicate that he too sought to solve this particular problem.)

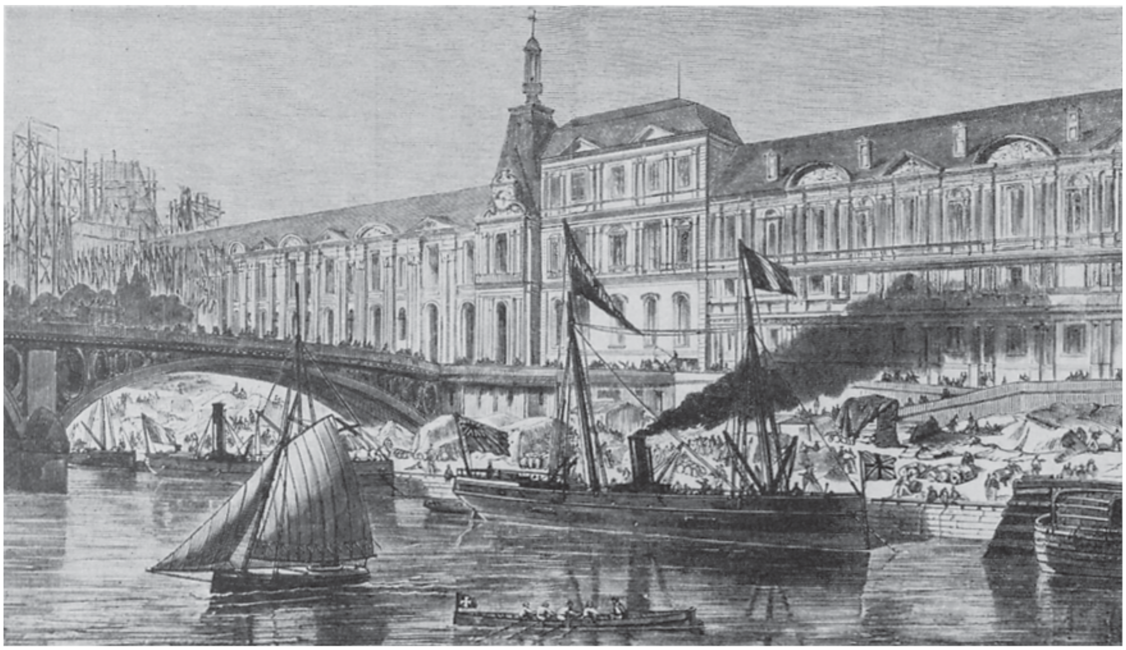
Machines

The more a new machine helped to boost production, the more rapidly it was generally adopted: weavers took slowly to Kay's fly shuttle since it only doubled output, but the silk-ribbon loom was readily adopted since it increased production 16–20 times, and silk throwing machines spread rapidly because they sent output soaring to 200–300 times the previous volume.

Since machines and ancillary equipment can be used to full advantage only when grouped together, their introduction hastened the advent of the big industrial plant. Still, early factories were generally of modest size. Even the fully mechanized cotton spinning mills of the

14. In 1816, only one year after Waterloo, the first British steamship docked at the Quai de Louvre, Paris. Contemporary drawing. By courtesy of Musée Carnavalet, Paris. Photo: Bulloz, Paris.
The steam engine revolutionized travel and transport, cutting delivery times for both raw materials and finished products.

15. The Société John Cockerill iron works on the banks of the Meuse at Seraing near Liège in about 1840. The installations included blast furnaces, forges, rolling mills and mechanical engineering shops. Founded by John Cockerill (1790–1840), an Englishman, it was the biggest industrial plant in Europe.
Lithographic print. By courtesy of Cockerill-Ougrée Providence S.A., Seraing.



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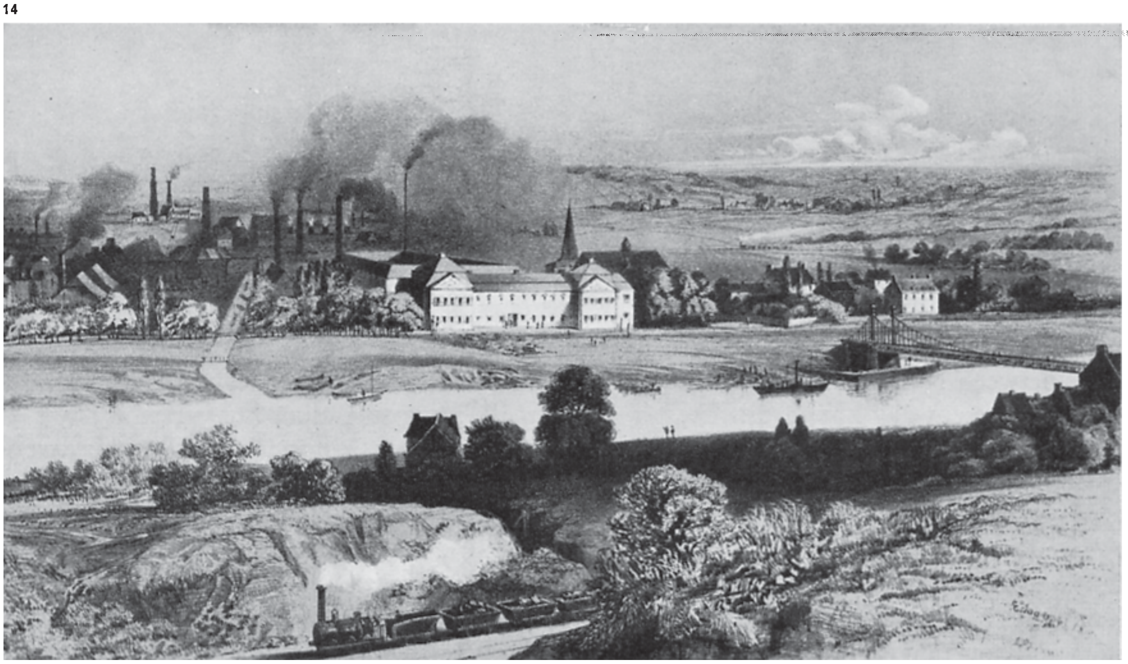

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16. The bridge and station at Water Street, Manchester, of the Liverpool & Manchester Railway, which started running passenger and freight services in 1830. Aquatint by H. Pyall of a drawing by T.T. Bury. From "Coloured Views on the Liverpool and Manchester Railway", London, 1831.

16

years between 1840 and 1860 were often very small by present-day standards.

Statistician Ernst Engel has estimated that, in 1839, cotton spinning mills in Saxony operated no more than 4,200 spindles on the average; today a coarse worsted spinning mill with less than 20,000 spindles is hardly viable and large mills have as many as 200,000. Reliable statistics show that early 19th century mills in France and Austro-Hungary were equally small, some still using horse-gins and windmills to power their machines. But there were notable exceptions. The Pottendorfer Baumwollspinnerei near Vienna, built after 1820, had 28,000 spindles and was in its day one of the biggest cotton spinning mills in the world. Arkwright, too, owned mills which were large plants by modern standards, and in France

17. Exhibitions and trade fairs were an outcome of the desire to exchange ideas, and to advertise and promote trade, which resulted from the production boosting effects of the factory system. The Great Exhibition of 1851 in London was the first to "unite the industry and arts of all nations", and it attracted more than 6,000,000 visitors. Here a transept of the famous Crystal Palace, a glass and iron conservatory-like structure erected by Sir Joseph Paxton using 4,500 tons of prefabricated iron parts and 600,000 cubic feet of wood. Lithograph by J. Nash. By courtesy of Deutsches Museum, Munich.

17

in 1808 Richard Lenoir possessed 39 cotton mills employing 14,000 operatives. Astonishing size characterized many silk throwing mills in operation before the first cotton mills were built. For instance, 2,000 operatives were employed in the mid-1700s by the von der Leyen's silk mill in Krefeld, Germany.

The social impact

Consumer demand

Adoption of the factory system resulted in a drastic drop in the prices of industrial products. This led to a consumer demand of previously inconceivable proportions which in turn prompted the erection of large manufacturing plants and the rapid industrialization of Europe and the U.S.A. Most of the profits made during this phase eventually flowed into the pockets of consumers rather than into those of industrialists and factory hands. In Britain, some of the "cotton lords" did manage to amass large fortunes, but the high element of risk involved in setting up a mill resulted in numerous unsuccessful ventures and bankruptcies.

Emigration to the towns

There can be no doubt that industrialization made life better for the working man, yet strangely enough the economic advantages inherent in the new manufacturing methods did not accrue to those primarily involved to the degree one would have expected.

Opinions differ as to the nature of the social conditions prevailing at the time. Enough reliable statistics are not yet available and contemporary reports tend to exaggerate the good or the bad because they were slanted to suit various vested interests. A biased picture is given even by official documents, for these stressed inadequacies and often drew general conclusions from isolated but striking cases. An idealistic picture was deliberately painted of the life led by agricultural labourers since estate owners were anxious to keep farm wages low and because high factory pay had prompted mass emigration to the industrial centres. Overcrowding in the rapidly growing towns certainly resulted in evils now difficult to envisage, but the rural population had lived under far worse conditions in the days before factories. In Scotland, farmhands had housed in windowless turf-block huts, their only furniture an iron cauldron dangling over an open fire.

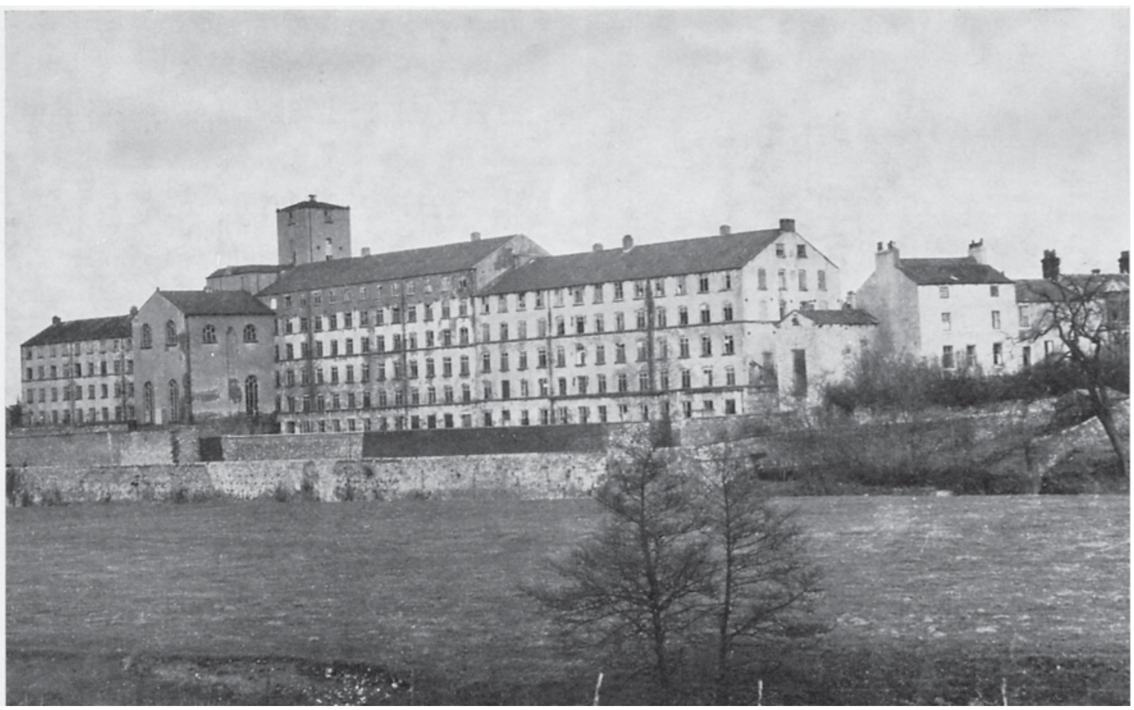
Dirt, heat, and stenches

Working conditions in the early mills were as bad and unhygienic as living conditions in working class homes in the new industrial centres. Cleanliness was of no importance, and no attempt was made to keep down dust. To maintain the temperature and humidity best suited to spinning, windows were kept closed all the time and fines were imposed on anyone trying to air a shed. In 1784, a medical report dealing with an epidemic of fever among Lancashire millhands also described working conditions in the cotton mills. These, it pointed out, were certainly very big buildings, but they had been designed to accommodate a maximum number of operatives. To save space, ceilings were as low as possible and most floors crowded with machines using considerable quantities of oil. The air was full of cotton dust which, settling on the oil and heated by friction, gave off a penetrating stench.—Proper ventilation of industrial buildings did not become general until after 1842.

Mills but no squalor

The first cotton spinning mills put into operation in the U.S.A. showed that industrialization did not necessarily result in squalor at home and at work. Thanks to industrial pioneers such as Samuel Slater, the evils found in British mills never accompanied technolog-

18. Low Moor Mill, Clitheroe, as it looks today. A complete 19th century spinning and weaving complex with housing, it was once one of the biggest mills in Lancashire. The first 3 storeys of the mill, the original small engine room on the right, and the house and cottages behind it, were all built in about 1800. The 4th and 5th storeys were added between 1820 and 1830, the new engine house on the left and the 6th floor on the centre section being additions made sometime after 1875.
By courtesy of H. Milligan A.R.P.S., Manchester Public Libraries.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ical progress in the States. To this difference none other than Charles Dickens bore reliable witness after his 1842 tour of the U.S.A. In the "American Notes for General Circulation", he recorded that all the female operatives he had seen in spinning mills were dressed in good and clean clothes, that he had noticed among them not one distressing face nor a single girl of whom he could say that, if she had to earn her living by manual labour, she would do well to find another job. Many of the conditions which for many years had been having an undesirable effect on British industrial towns did not exist in America.

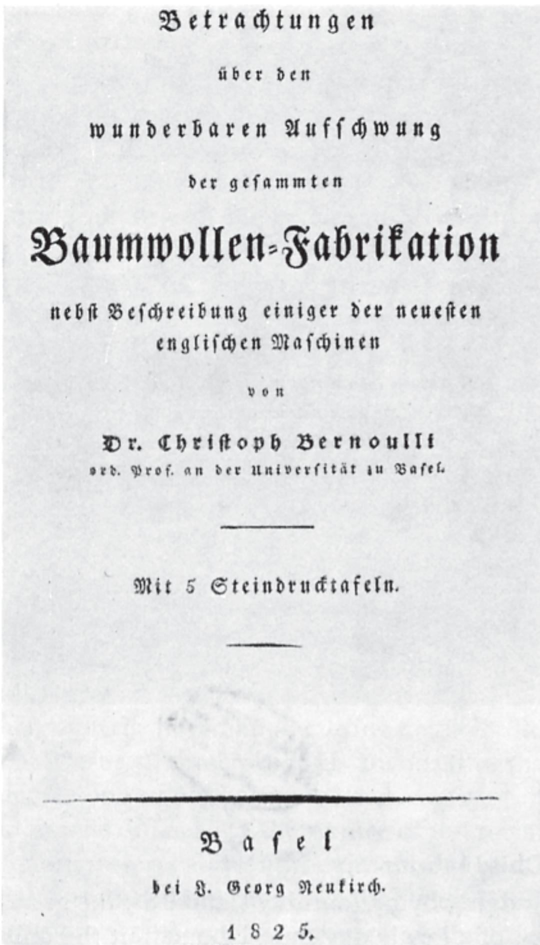
Child labour

Judging by present-day standards, the greatest of all evils was child labour. But the mills did not invent it, they were only the most glaring example of its exploitation. An official British report compiled in 1833 even pointed out that, of all the outdoor and indoor labour required of children, that in the mills was the least strenuous and unhealthy.
Child labour was being exploited long before mills were built or hired juveniles. The opinion generally held and shared even by those interested in child welfare, was that children were there to be put to work and should earn their

The glaring contrast between the promised benefits of industrialization and the social evils it initially promoted in mill towns was highlighted by the arguments of contemporary writers:

19. Cover page of a treatise, published 1825, in which Basle physicist/technologist Christoph Bernoulli (1778–1863) defended the factory system against the bitter criticisms of Geneva economist Simonde de Sismondi.

20. Cover page of a pamphlet by Robert Cruikshank (1789–1856) aimed at the free trade advocates who called for the abolition of slavery but saw nothing wrong in letting children toil in the mills.



Betrachtungen

über den

wunderbaren Aufschwung

der gesammten

Baumwollen-Fabrikation

nebst Beschreibung einiger der neuesten englischen Maschinen

von

Dr. Christoph Bernoulli

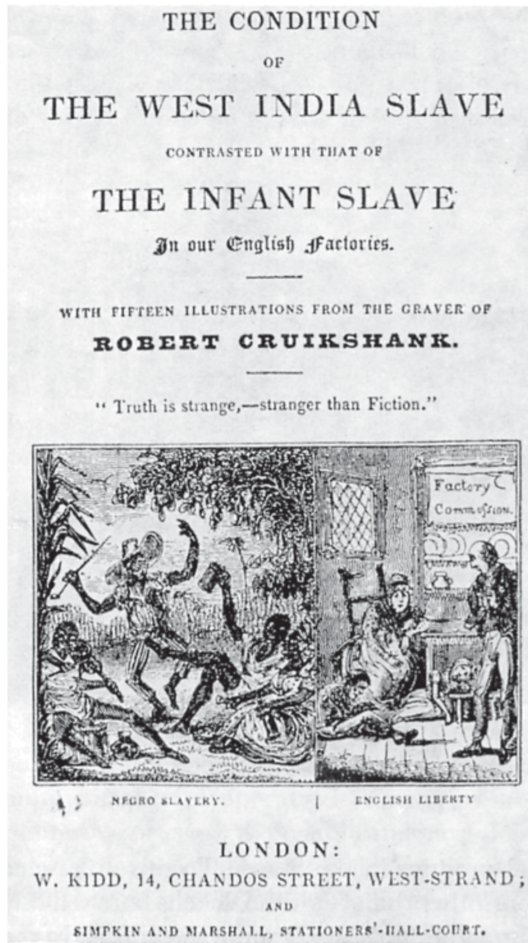
ord. Prof. an der Universität zu Basel.

Mit 5 Steindrucktafeln.

Basel

bei J. Georg Neukirch.

1825.



THE CONDITION

OF

THE WEST INDIA SLAVE

CONTRASTED WITH THAT OF

THE INFANT SLAVE

In our English Factories.

WITH FIFTEEN ILLUSTRATIONS FROM THE GRAVER OF

ROBERT CRUIKSHANK.

"Truth is strange,—stranger than Fiction."

Factory Commission

NEGRO SLAVERY. | ENGLISH LIBERTY

LONDON:

W. KIDD, 14, CHANDOS STREET, WEST-STRAND;

AND

SIMPKIN AND MARSHALL, STATIONERS'-HALL-COURT.

21. An anti-child labour cartoon. Hard work was regarded as a necessary means of disciplining the young until the mills made the evils of child labour apparent, thus leading to reforms which resulted in factory laws.

own living from their third, at the very latest from their fifth to sixth year onwards. Hence mill machines provided a welcome opportunity to put children to work at the earliest possible age. If they were not employed in the mills, it was feared, children would degenerate morally and physically.

The thought of toiling children troubled the general public very little. In 1788, when the Manchester mills sought tariff protection against severe competition from cheap cottons imported by the East India Company, they even pleaded in their favour that they made extensive use of child labour. These children, they argued, were able to support themselves at an early age, thus being of service to their parents and the community.

A humanitarian's attitude

Heinrich Pestalozzi, the Swiss reformer in the field of education (1746–1827), argued that the children of the poor should be "brought up to endure poverty". He stressed that they would only become unhappy malcontents if conditions in institutions were better than those with which they would have to contend in their adult lives. At his own industrial school for the poor in the "Neuhof", Pestalozzi had the support of the Bernese government when he put six-year-olds to work carding, spinning, and weaving.

Education and machines eliminate child labour

In the end, mills and factories in Britain and Switzerland gave up hiring children not because people were worried about their health, but because children could not very well go both to work and to school. From 1833 onwards, government mill inspectors in Britain kept a strict check to ensure that every child attended school for at least two hours daily; they were, in fact, the men who made the state education system work.

Although mechanization at first encouraged the use of cheap child operatives, special machines such as the ribbon loom subsequently made them redundant. In the knitting industry, hundreds of six to ten-year-olds once used to hunch for soul-deadening and health-

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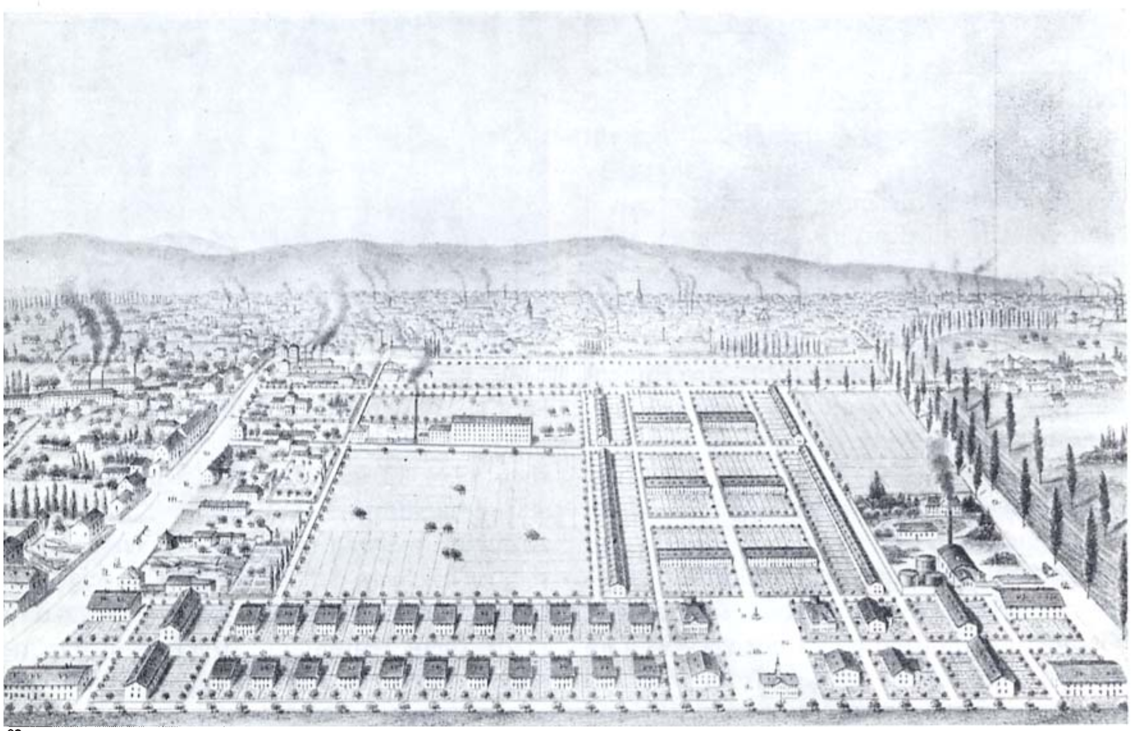

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Mass emigration to the industrial centres and lack of planning resulted in chaos and unhealthy overcrowding in most early mill towns. Where industrialization came more slowly, attempts were made to keep developments under control.
22. Mulhouse, the Alsatian textile centre, in the early 19th century. Printing works have been set up around the old town, which has a dense population but has undergone no marked changes. Lithograph by G. Engelmann from "Manufactures du Haut-Rhin", 1822–1824. Photo: Musée de l'Impression sur Etoffes, Mulhouse.
23. In about 1850 the Société Industrielle organized the construction of a workers' settlement with housing and gardens in Mulhouse, inspiring similar solutions in other industrial countries. Lithograph by H. Maurer from the "Bulletin de la Société Industrielle de Mulhouse", 1855.

wrecking hours over small tables in poorly-lighted rooms, threading needles for their fathers and brothers. It was their plight which prompted one man to invent the threading-up machine. Introduced in 1890, his invention found ready acceptance and 6,500 machines were in use only 20 years later.

Women and mills

Criticism of the factory system includes the peculiar accusation that it made possible and encouraged the use of female labour. This is hardly true. On the contrary, the invention of machines such as the spinning jenny, the self-acting mule, the carding machine and the jacquard loom opened up to men a field that had for thousands of years been the almost exclusive domain of women: spinning and weaving.

The factory system is also held responsible for the soul-destroying monotony of much mass-production work. But who would argue in all seriousness that a woman finds it more boring to mind a ring-spinning frame than to twirl a hand-spindle, or more monotonous to tend an automatic loom than to work at a hand-loom. Prior to the invention of spinning machines and power looms, a woman's whole life was dominated by the never-ending tasks of spinning and weaving. In ancient Greece, her wool basket and spindles even followed her into the grave; they were the symbols of her station and calling.

Social welfare

Employee welfare and sick pay was one of the problems which confronted early industrialists. Under the guild system, provision was regularly made to take care of masters and journeymen who fell on evil days. In the new industrial society which came into being through the concentration of working class families in and around factories, no such provision was made for loss of earning capacity. An adequate social relief system was not evolved for generations.

Nevertheless, a few men were ahead of their times. One such was Jeremias Elias Gülich, the author of the "Vollständiges Färbe- und Blaichbuch". Writing in 1781, he stated that a savings and sick pay fund should be set up whenever a mill was built. A "kreuzer" should be deducted from every man's pay every day and paid into this fund, one of the older operatives keeping a book. At the end of the year, the mill owner should in his turn pay into the fund a sum equivalent to that contributed by his employees or, alternatively, he should deposit with the fund at the end of every month a sum equivalent to every operative's pay for a whole or half a day. Unfortunately, wrote Gülich, such arrangements were rarely made, since either the workers or their employers grudged the contributions they would have to make.

Resistance to industrialization

Hard pressed by competition from the mills, handicraftsmen resorted to violence. It was the factory system rather than the machine to which they were opposed, but they took to wrecking the latter. Machines are often equated with factories although they are not one and the same thing. Some factories use little or no machinery, and machines were being used long before the advent of textile mills. But the two are closely associated; machines made the early mills a success, hence they became the emblems of industrialization and the objects of impoverished craftsmen's fury. However, not every machine inspired the same degree of aversion.

"Good" and "bad" machines

Why did men smash spinning frames but not sewing machines? Why did they oppose the use of power-looms but not that of hand-looms? Writing in 1827, Basle physicist/technologist Christoph Bernoulli commented: "Although both perform the same function, water-wheels are held to be useful and steam-engines to be harmful... We should tear down bridges that everyone must hire a boatman, and break up roads that all goods must be carried on men's backs." Bernoulli's caustic comments in favour of the factory system were aimed primarily at the vehement anti-factory polemics of Simonde de Sismondi of Geneva, a leading economist of the day.

Did the advent of mills and factories do the working man more harm than good, and what were the real effects of technological progress on the economy as a whole? These are still questions for which there is no fully satisfactory answer. Statistical data clearly indicating that factories provide work and a once undreamed-of standard of living for millions are not conclusive evidence. As the supposed cause of all this prosperity, the factory system and its ramifications cannot be studied in a vacuum without reference to the roles played by other important factors such as the growth in population, commerce and trade, etc.

Fear of increased productivity

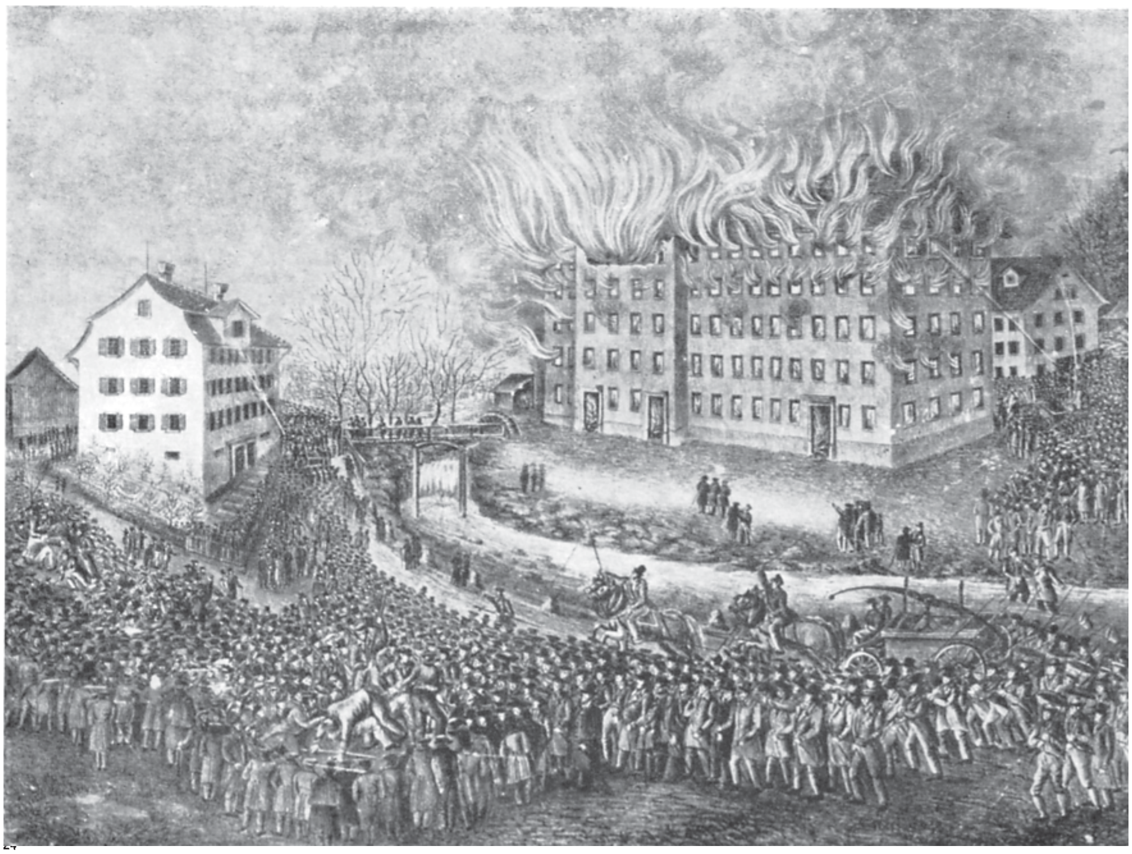
Technological progress encountered bitter opposition whenever it boosted production. New machines found ready acceptance only when they were designed to do tasks which were particularly stupefying or caused deformities, such as grinding corn or kneeing into position the parts of a spinning mule (which resulted in the bone deformation called "spinner's knee"). Kneading machines were installed in bakeries when journeymen refused to work in shops where they were required to do everything by hand.

Occasionally, the authorities even prohibited the use of production boosting manual techniques. In the latter half of the 13th century, the "Livre des Métiers" forbade silk spinners in Paris to use two hand-spindles simultaneously. Even the spinning wheel must have been banned at one time or another, otherwise weavers' regulations issued in 1298 in Speyer, Germany, would not have stated specifically that wheels might be used to spin warp yarns.

The ban on ribbon looms

The ban imposed by the magistrates of Danzig, in 1580, on the use of ribbon looms is the best known of early official anti-machine laws. According to unconfirmable reports published in Venice in 1636, the Danzig inventor was

24. The Corrodi cotton mill at Uster on fire on November 22, 1832. In Switzerland as in other countries, resistance to mechanization led to riots, machine wrecking, and arson.
By courtesy of Graphische Sammlung der Zentralbibliothek Zürich.



either drowned or burned together with his loom.

The first reliable reports on ribbon looms came from Holland. The inventor of the "lintmolen" was William Dircxz of Sonnevelt, who built a 12-ribbon loom at Leiden in 1604. In England, his machine was called a "Dutch loom" or "engine loom"; in France, it went by the name of "métier bâlois" or "zurichois". Dircxz's invention put an end to the weaving of narrow fabrics by children, for only a grown man had strength enough to activate its mechanism. Water-wheels were not used to power ribbon looms until Kay invented the appropriate device, patenting it in 1745.

Three of Dircxz's looms were bought at 550 florins each and another three were rented by a leading Leiden firm in 1604. Their use was strongly opposed by eight local entrepreneurs using 126 hand-looms and at least one was publicly burned in Bruges, but 40 had been installed in Leiden by 1610.

That same year the first "engine looms" appeared in London, where hand-weavers lodged bitter complaints and secured what proved to be a virtually ineffective prohibition of their use. In 1675, London weavers staged serious riots, burning the new looms in the streets. They enjoyed the backing of the general public and some of the troops called out to suppress the riots even gave the weavers their support.

A contemporary, official English report stated, in quite modern terms, that "engine looms" made fabrics as good as those produced by "single looms" and that, if their use were encouraged, they would provide more jobs than the latter for the poor. In Holland and in France, one man using an "engine loom" could turn out 12 ribbons 432 yards long in only two days, whereas with "single looms" it took three to four men to do as much work in so little time. For the same reasons that "single loom" weavers objected to "engine looms", the report added, selfish and jealous people could also decry the use of machines in water-mills, sawmills and iron works, of ploughs, presses and dockyard derricks, and of many other ingenious, useful and profitable inventions in use throughout England.

Silk throwing mills

An equally sensible appreciation of mechanization was shown in the 14th century by town authorities in Upper Italy when they readily granted asylum and numerous privileges to political refugees with detailed knowledge of Lucca's silk mills. In Aachen, on the other hand, local hand-spinners joined forces in 1412 to make the town council forbid one Walter Kesinger to build a throwing mill which would "cost many people their livelihood". Not until 1599 did Aachen's authorities realize that the ailing silk trade should be revived by building "a new spinning mill".

In 1737, the introduction into England of silk mills led to rioting by female cottage industry operatives engaged in the manufacture of buttonhole silk at Macclesfield near Derby. Numerous rioters were arrested only to be liberated by force.

Frame-breakers

In Basle

In Basle on July 21, 1751, "an army of stocking weavers and a few women" descended on the factory owned by Hieronymus Marti, smashed the windows and dragged away all the machines. In 1827, Christoph Bernoulli noted that Basle's ribbon weavers had petitioned 200 years earlier against the introduction of power-looms, pleading that "The invention do make all ribbon weavers breadless, ruining the trade and depriving the public treasury of income, being uncharitable and unchristian, earnings being anyway excessively reduced and low". When this petition was submitted, only about 20 families were earning a living by weaving ribbons; in 1827, some 2,000 families were making ribbons on power-looms.

In England

Handicraftsmen, it is widely believed, opposed only the introduction of power-looms but not that of spinning frames. This is an error.

According to the records of the Lancaster courts of assize, greater and lesser riots occurring in autumn 1779 resulted in the destruction of 60 spinning frames, 31 carding engines,

25. Zürich cotton spinner Hans Caspar Escher (1775–1859) was appalled by mechanization in British mills he visited in 1814, but subsequently he changed his mind, started designing his own machines and made Escher Wyss & Comp. a leading mill machinery manufacturer.
Lithograph by J. Kriehuber, 1851. Photo: University Library, Basle.

26. In 1812, romantic poet Lord Byron (1788–1824) in his maiden speech in the House of Lords opposed the death sentence for textile machine wreckers, calling for a more sympathetic attitude towards men who felt their existence threatened by mechanization.
Painting of Byron in Greek national dress by Thomas Phillips (1770–1845). By courtesy of the National Portrait Gallery, London.

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Cottage industry operatives worked long, monotonous hours in dark, damp cellars with no guarantee that their labour would be in constant demand, yet their life was often depicted as idyllic in contrast to work in the mills.

27. British carded-yarn spinning mill with self-acting mules, about 1830. Etching of a drawing by T. Allom. From E. Baines's "History of the Cotton Manufacture in Great Britain", London, 1835.

28. Hand weaving fine muslin somewhere in East Switzerland in the early 19th century. The weaver is using the flying shuttle introduced shortly after 1800. Aquatint of an aquarelle by Johannes Schiess (1799–1844).

and 23 twisting machines. At about the same time, spinning mills at Preston, Oldham and Bolton were destroyed by arson. But the economic distress which prompted handicraftsmen to resort to violence was the fault of politics and not of the mills.

The Luddites

From 1811 to 1813, organized bands of rioters protested against wage reductions and competition from poor quality goods by smashing mill machinery, first in Nottingham and then in Yorkshire, Lancashire, Derbyshire and Leicestershire. Generally operating at night and masked, these rioters were named "Ludds" or "Luddites" after a real or imaginary leader known as "General Ludd".

The Luddites were supported by public opinion, and they abstained from bloodshed and violence against living beings until a band of them was shot down by troops in 1812 at the request of a threatened employer. This man was subsequently murdered.

Severe repressive legislation, opposed by Lord Byron in a House of Lords speech, led to a mass-trial at York in 1813. Many hangings and transportations were the result. The real "King Ludd" must have been among the victims, for the elaborate organization collapsed.

The depression which followed the peace of 1815 and a very bad harvest resulted, in 1816, in renewed, highly organized Luddite style rioting which spread from Nottingham over almost all the kingdom. Vigorous repressive measures and, especially, reviving prosperity brought the movement to an end.

Switzerland's "Usterhandel"

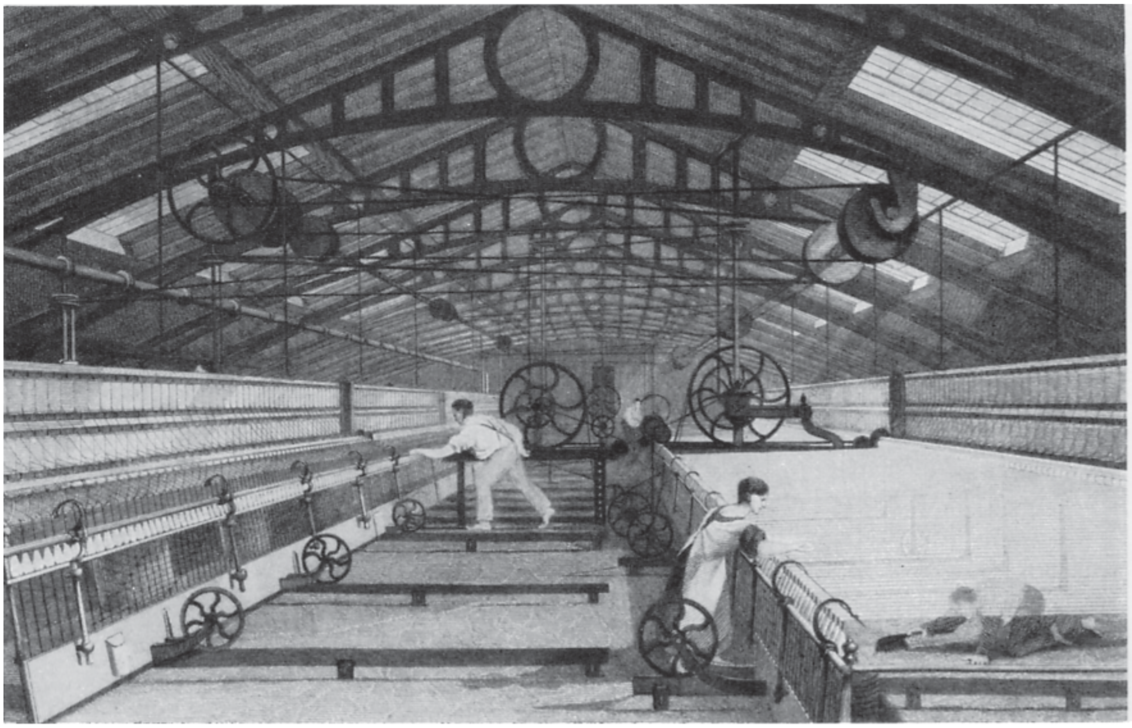
Arson at Uster in 1832 was the only case of Luddite type violence to occur in Switzerland, and it had a political background. Public opposition to the imminent introduction of power looms previously had been manifested in a number of petitions. The prohibition of machines, it was generally felt, was of greater importance to the maintenance of liberty than the 1830 constitution. It was argued that "For the craftsman, freedom to exercise his trade means the liberty to weave; he loses this freedom if no one will give him work."

Other large-scale anti-machine riots occurred in 1831 at Lyons, and in 1844 when both the cotton printers of Prague and the linen weavers of Silesia resorted to violence.

A mill-wright's doubts

Fears that the coming of the power-loom meant overwhelming competition and poverty were widespread in about 1800. The thought of mechanization scared even Hans Caspar Escher of Zürich, the mill-wright and cotton spinner who founded Escher-Wyss. After visiting mills in England and Scotland in 1814, he wrote: "A number of mechanical weaving mills alarmed me and made me fear that we shall of necessity have to copy these installations if we intend to compete with the French and English; fortunately, they are suitable only for making common fabrics . . . Each loom produces 10–14 yards per day, a child being paid a florin to mind two at a time."

In view of this general alarm it is as well to note that, in England, power-looms spread rapidly but did not oust hand-looms for a long time; in 1830, as many hand-looms were in use as in 1820, even though the number of power-looms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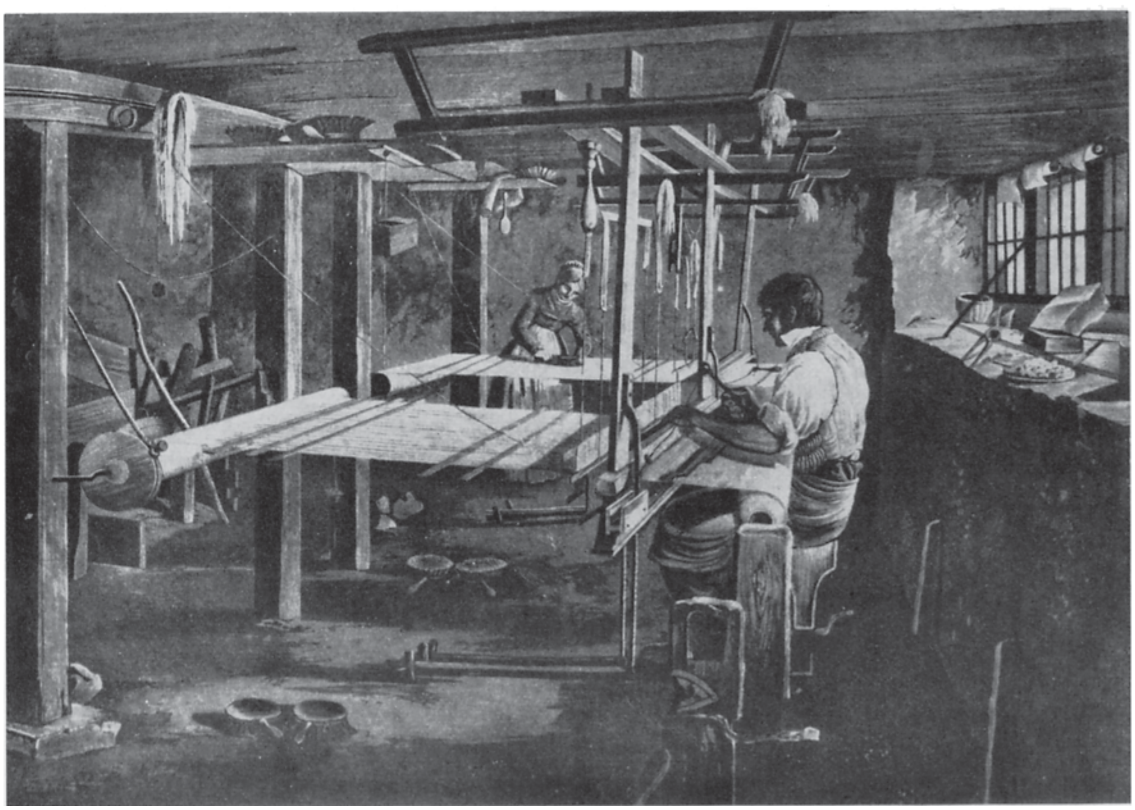
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Leonardo da Vinci – a herald of mechanization

had increased from 14,000 to 55,000. In Germany, the economic distress of weavers was definitely due to factors other than competition from power-looms; in 1861, only 350 power-looms but 120,278 hand-looms were in use within the boundaries of the "Zollverein" (German Customs Union). Similarly, it was not mechanization that ruined the wool industry's cloth makers. In Switzerland, the hand-loom remained in use for a remarkably long time, especially among silk spinners.

The "idyllic" cottage industry

Viewed as a family business, the cottage industry was frequently painted in glowing colours. Among those who pictured it as an idyll were William Radcliffe, who made his fortune in the business; Jean-Jacques Rousseau; and the artist Heinrich Meyer of Stäfa, who described local conditions in detail in a letter he wrote in 1810 to Goethe (who quoted him in "Wilhelm Meisters Wanderjahre"). However, the factual autobiography of cotton merchant Ulrich Bräker and the notes made by Father Steinmüller gave a much grimmer picture of the lives led by cottage industry operatives in Toggenburg and Canton Glarus.
Working men abandoned their opposition to the factory system and mechanization in the end. But the change of attitude involved did not occur until the latter half of the 19th century.

It would be unjust to assume that most great inventors were inspired primarily by the thought of the practical uses to which their ideas could be put. It would be particularly unfair to think this of Leonardo da Vinci. Still, it would also be an error to regard as nothing but the product of a gushing, lively imagination the innumerable sketches of machines in his Codex Atlanticus.

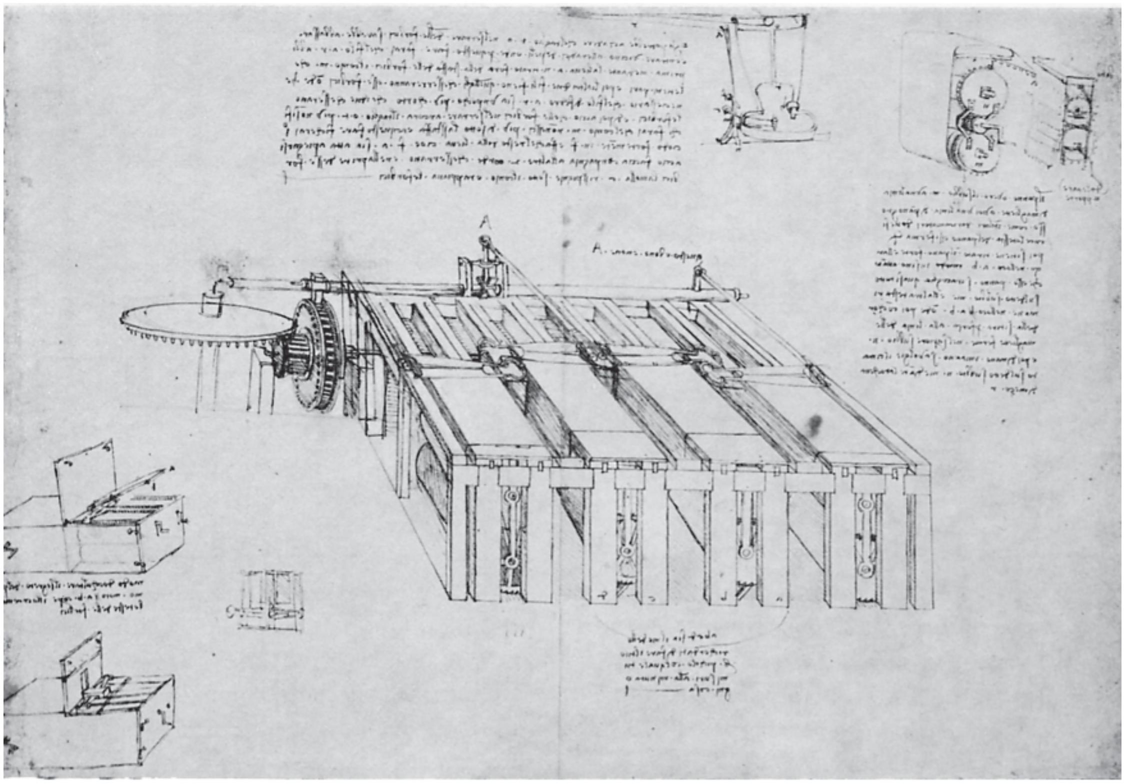
Referring to his design for a sewing-needle grinder (Codex Atlanticus, f.341 v.), Leonardo wrote: "A hundred times 400 (needles) an hour makes 40,000 an hour and 480,000 in 12 hours. But let's say 4,000 thousand (representing the work of ten machines) which at 5 'soldi' per thousand would make 20,000 'soldi', adding up to 1,000 lire per working day and, if one were to work 20 days a month, 60,000 ducats per year." That he seriously intended to put this particular invention to practical use is indicated by another entry: "Tomorrow morning, on January 1, 1496, I shall have the broad belt made and (carry out) the test".

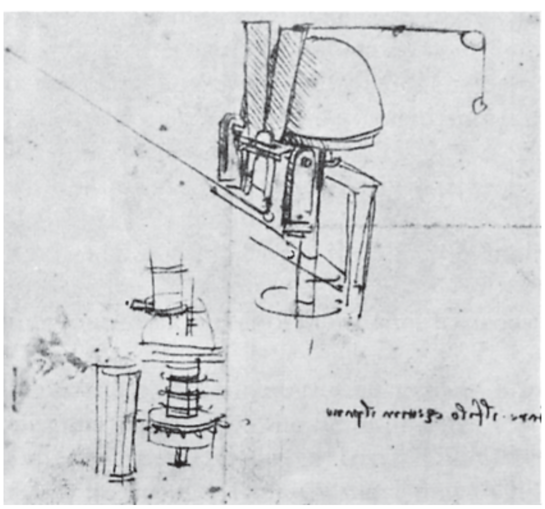
The rotary principle

A realistic approach is also apparent in Leonardo's sketches of textile machines. Aiming primarily to cut the time needed to complete individual operations and to accelerate the working speed of machine parts, he deliberately sought to base his designs on the rotary principle, thus eliminating the drawbacks inherent in reciprocating motion. The advantages of rotary motion were little known and widely opposed at the time, for Leonardo saw fit to argue his case in notes referring to his design for a dredging machine.

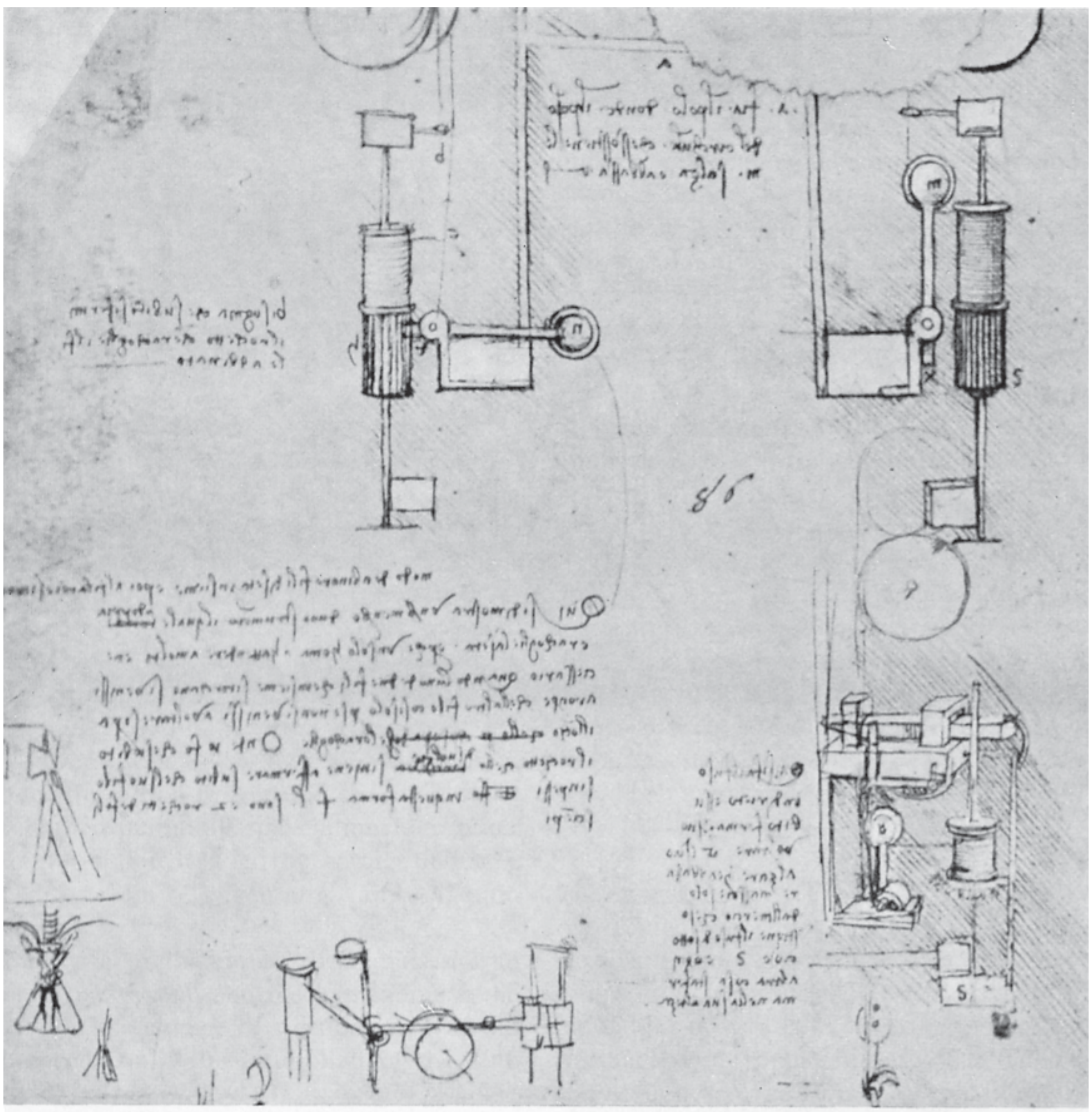
29. Cropping machine designed to shear four fabrics simultaneously. This sketch from the Codex Atlanticus clearly demonstrates Leonardo da Vinci's (1452–1519) efforts to save time and labour by setting up mechanically activated tools in series. A single drive-wheel simultaneously opens and shuts the shear blades, moves the shearing beam and the cloth take-up device to and fro, and winds the fabrics off the cloth beam and via the shearing beam onto the tension roller. Photo: Biblioteca Ambrosiana, Milan.

30. Leonardo da Vinci's sketch of a cap trimming machine (Codex Atlanticus). The caps rotate slowly on their own axes, sinking as they turn, while the tangentially inclined shear blades are activated by cords.



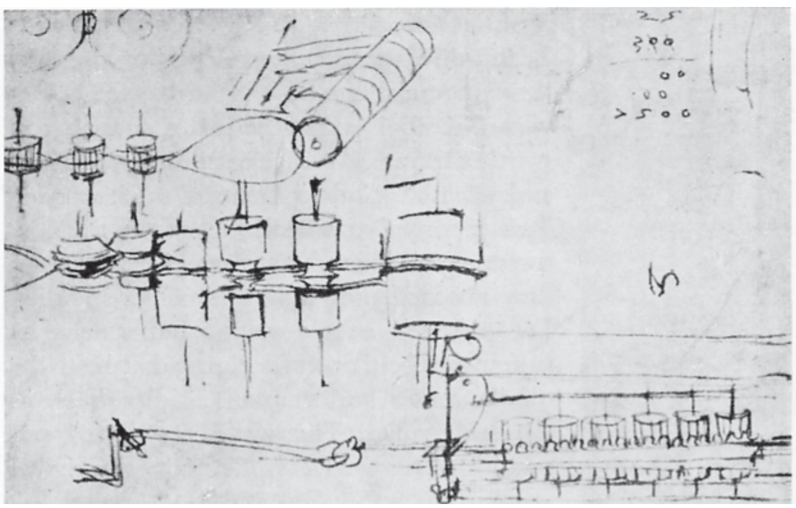


31. Stop-motions for doubling frames from Leonardo da Vinci's Codex Atlanticus. The upper part of the sketch shows the doubling frame, in motion on the right, at rest on the left. Yarn guides lead each of two yarns over a roller (only the front roller is visible) to the spindle where they are doubled. If a yarn breaks, the lever bearing the roller drops and its extension blocks the lantern-type drive, thus stopping the spindle. A cam assures even take-up of the doubled yarn by raising and lowering the stop motion. On the right is a drawing of a stop-motion with an indirect, spring-activated mechanism.
Photo: Vicari, Lugano.



32. Spindle drive mechanism depicted in the Codex Atlanticus. Leonardo da Vinci sought to improve on the clumsy drive employed in Lucchese-type throwsters by running a belt or cord zigzag between the spindle bases and round an idler back to the drive roller.
Photo: Vicari, Lugano.

Reproduction of Leonardo da Vinci's sketches by courtesy of the Biblioteca Ambrosiana, Milan. Additional data were kindly provided by Dr. A. Paredi.



32

Shearing and cutting machines

The easiest and most direct way to cut production time is to eliminate manual labour in favour of work done by mechanically activated tools, it then being possible to break down processes into specialized operations capable of being accelerated. This approach is evident in Leonardo's sketches of cloth-cutting machines, in which he progressively abandons the manually operated tool as he develops his ideas. In his first designs he retained the ordinary, spring-loaded shears of the time, activating them by levers or cords while fabric was automatically moved through their jaws. Then he substituted large, directly opposed blades for the shears. Finally he sketched huge machines capable of cutting four to six pieces of fabric simultaneously (Fig. 29).

Leonardo sketched interesting machines for clipping (trimming) the hemispherical cloth caps of the period and area. In his explanatory notes, he wrote: "The caps move down while the shears stay where they are, swivelling only on the transverse pins". The sketch shows the shear blades cutting tangentially at a steadily increasing angle while the caps rotate slowly all the time. Like the teasing machines he designed for cloth weavers, he envisaged the cap-cutting machine set up in series (Fig. 30).

Ropemakers' wheels

Leonardo's endeavours to increase productivity by the multiple and independent, but simultaneous, execution of an operation are most clearly apparent in his sketches of ropemaking machines. Drawn at a time when the simple ropemaker's wheel with a single spinning hook was just coming into wider use, his design for a ropemaker's wheel with three simultaneously revolving hooks was something really new. In another sketch (CIBA Review No. 59, p. 2164), Leonardo went even further and drew a machine for spinning at least 15 ropes in one operation.

32a. Extensively automated assembly line in a modern car factory; the roofs are being rammed into place and welded. By courtesy of Volkswagenwerk AG, Wolfsburg.
Automation is the latest development in man's striving to eliminate both strenuous physical labour and repetitive, mind-deadening tasks. The giant stride from Leonardo da Vinci's machines to the car assembly line clearly illustrates the march of technological progress, a phenomenon always feared by some and acclaimed by others.


32a

Twisting frames
Leonardo's detailed knowledge of the silk-throwing machines built in Lucca (CIBA Review No. 59) is apparent in his drawings of twisting frames. At Lucca, spindles were driven by leather clad segments of thick wooden discs (a sort of cogwheel). Seen from the side, these segments had a square cross-section; they are visible at the bases of the spindles. Leonardo sought to develop a better drive by running a belt or cord zigzag between the spindle bases and round an idler back to the drive roller. This was the system eventually utilized in Diderot's and Arkwright's frames (Fig. 32).
Twisting frames may also be what Leonardo sought to depict in those sketches in the Codex Atlanticus (f.377 v. and f.393 v.) generally interpreted as showing spinning frames (CIBA Review No. 28, p. 1009). There is no indication of an automatic fibre feed although hand feeding would have meant employing one operative for each spindle, thus achieving nothing which ordinary spinning wheels could not have done as well. Nipping devices or rollers which grip and attenuate the roving are nowhere indicated or hinted at, although they played a vital role in ensuring the success of English cotton spinning frames. In an explanatory note to one design, Leonardo wrote that "non à altra faticha che a *ritorcere* il filo", thus stressing twisting (ritorcere) and not spinning (Fig. 32).

Stop motions
Leonardo's most modern designs were those for stop motions to be used on doubling frames in throwing mills. He drew many, often very complicated, sketches. In these the two yarns

to be doubled are led over rollers or through eyes on levers in unstable equilibrium; if a yarn breaks, the lever drops and its extension blocks the drive, bringing the spindle to a stop. Leonardo wrote (freely translated): "Here is shown part of a machine which doubles and reels silk. Since one man must tend many (machines), it is necessary to ensure that, if one of the two yarns being doubled should break, the other will not run on alone past the point at which it converged with the first. Therefore I cause the drive which takes it (the yarn from the feed package) to stop whenever the yarn breaks..." This design would have cut intervals between individual operations and enabled one man to supervise several spindles without detriment to product quality (Fig. 31).

Recommended reading

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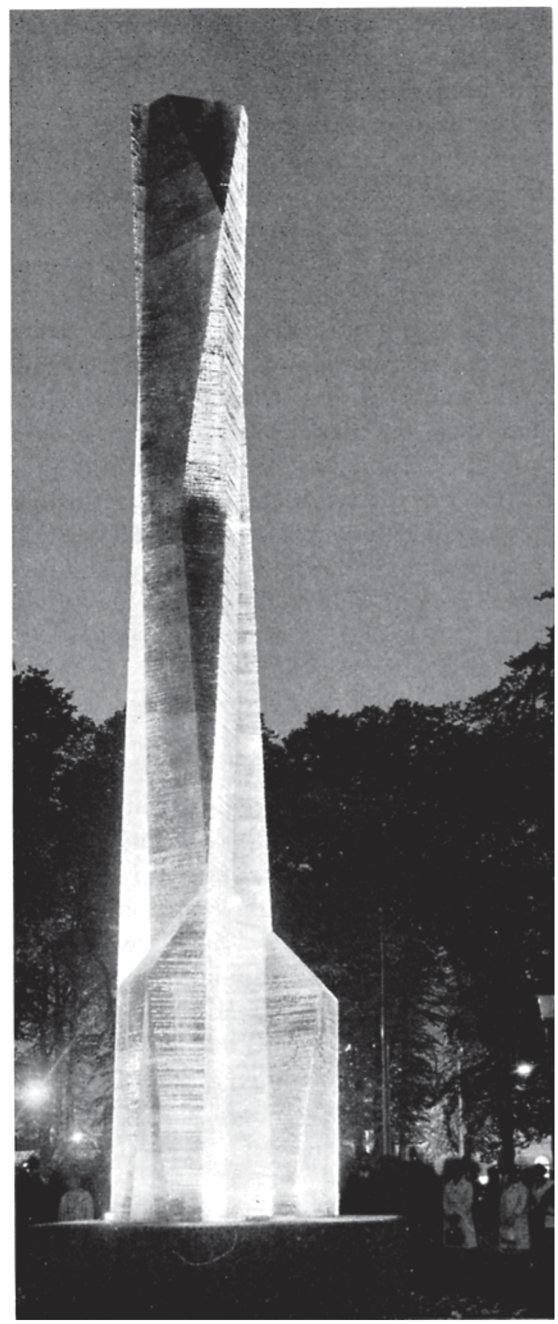
CIBA Group

Sweden

"Prisma", Norrkoeping's new landmark
Norrkoeping, a town 105 miles southwest of Stockholm, now owns one of the world's most extraordinary pieces of monumental sculpture. Called "Prisma", the new landmark is a glass obelisk standing 37 feet high and weighing 33 tons. It is the work of Vicke Lindstrand.
Pioneering a technique, Lindstrand assembled the huge polyhedron by glueing together 3,500 pieces of glass made by the Emmaboda Works with several hundred pounds of CIBA epoxy resin (®Araldite). Because the refraction of the extremely thin glued joints is indistinguishable from that of the sea-green glass itself, the performance of the "stabile-mobile Prisma" is optically perfect. The sculpture changes colour in constant interplay with the light of its surroundings.
"Prisma" rests on a base weighing 55 tons, supported by four concrete pillars sunk 89 feet into the earth. Floodlights built into the pedestal illuminate it at night.
Lindstrand took three months to construct his sculpture, working at a constant temperature in a tent erected over the site in the park of the Folkets Hus. The result, he says, exceeded his expectations.
The unveiling of "Prisma" was attended by a crowd of 15,000. Since then, Norrkoeping has been invaded by artists, critics, photographers, and municipal officials eager to examine what is probably the world's largest piece of glass sculpture.
"Prisma" was financed by a donation from the Gustaf and Carolina Petersen Foundation.



Norrkoeping's "Prisma", the latest work of Sweden's Vicke Lindstrand. Standing 37 feet high and weighing 33 tons, it is made of 3,500 pieces of glass glued together with CIBA epoxy resin.

U.S.A.

CIBA's new southern district headquarters

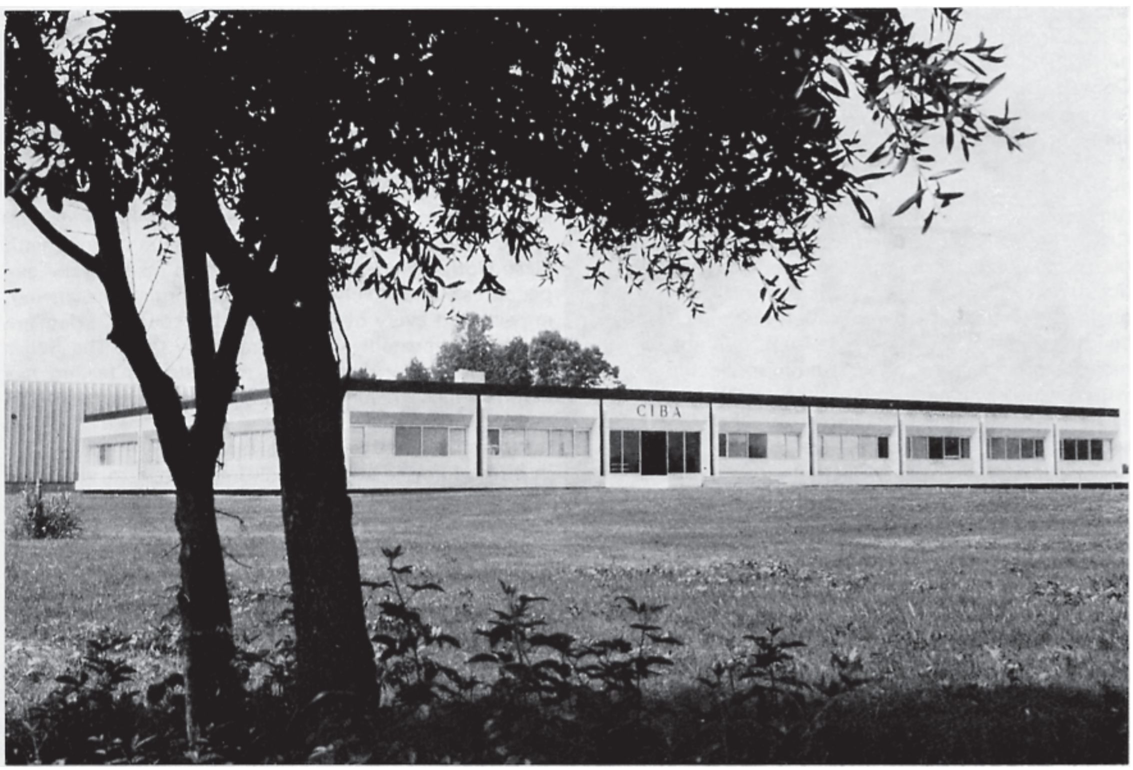
CIBA Chemical & Dye Company, Fair Lawn, N.J., opened new United States southern district headquarters in Charlotte, North Carolina, in summer 1967. Employing 60 persons, the installation is the largest of the company's five district headquarters.

The facility consists of two buildings of contemporary design accommodating administrative and sales offices, laboratories for customer service, and a warehouse. It is located in Atando Industrial Park on an 18-acre tract selected to provide ample room for future expansion.

Charlotte itself is not only the nucleus of a prospering urban industrial region, but also the hub of textile research and technology in the U.S.A. It is located near major universities which specialize in textile curricula. The first CIBA office in the city was opened in 1935.

With its new district headquarters now operational, CIBA Chemical and Dye Company can service customers throughout the southern United States more speedily and thoroughly than ever before. It is a major supplier of specialities for industries producing textiles, paper, paints, plastics, leather, soaps and detergents, and printing inks.

CIBA Chemical and Dye Company's new southern district headquarters in Charlotte, North Carolina. The building in front houses offices and laboratories for customer service, the one behind is a warehouse.



A CIBA product for every dyeing, printing, and finishing process!

Acrylic fully fashioned goods

Pre-scouring	®Ultravon JU, ®Silvatol SO
Bleaching / optical brightening	®Uvitex ALN, A double
Dyeing	®Deorlene Fast dyes for goods calling for the best possible fastness properties, Deorlene and ®Cibacete dyes for pale shades
Softening	®Sapamine NP, OC, PA

Cotton flameproofing agent fast to washing at the boil and drycleaning

Attempts to reduce or completely eliminate flammability in textiles have never been lacking, and nowadays work on such projects is encouraged by legislation and safety regulations. The example was set by the U.S. government's "Flammable Fabrics Act" of 1953, the Flammable Fabrics Amendment bill being passed in 1967 and authorizing the development of stricter standards. Meanwhile, Switzerland and other countries have banned or are banning the use of highly flammable fabrics in the manufacture of apparel.
In the past, inorganic salts such as borax, ammonium phosphate, ammonium sulphate, etc. were frequently employed to impart flameproof finishes to cellulosic fibres. These will no longer serve today, since a good flameproof finish must meet the following requirements (A. F. Childs, Dyer, Nov. 6, 1959):

- Simple application
- Good flame inhibition and no afterglow
- Fastness to washing and drycleaning
- No impairment of colour fastnesses of dyeings
- Negligible modification of handle or of the mechanical properties of the fibre
- No toxic effects
- No skin irritation
- Compatibility with other finishing agents

Not all these requirements are met by most of the flameproofing treatments in use at present. These include those based on organophosphorus compounds, which react with cellulose to give effects fast to washing and drycleaning, and which are applied together with nitrogen compounds that act both as fixatives and extenders. When exposed to heat, the nitrogen compounds reinforce the combustion inhibiting effects of the organophosphorus compounds by emitting flame dampening gases. Good flameproofing effects are obtained only when the finish on the fibre contains at least 1.8% each of phosphorus and nitrogen. As a rule, the nitrogen content will be somewhat higher.

The stability to laundering of organophosphorus based finishes is assured only if these compounds are stable to alkali treatments and/or metal ions, and if they are not converted into the corresponding phosphates, which have very little flameproofing effect.

®Pyrovatex CP
Pyrovatex CP is a durable flame retardant developed and marketed by CIBA Limited. It is recommended for flameproofing cotton fabrics which are to be made up into

protective clothing,
nightwear,
furnishing fabrics,
cotton sheeting and tablecloth fabrics.

Pyrovatex CP has the following advantages for the finisher:

- Handy, liquid form.
- Simple application on conventional machinery (Pad-cure method).
- Compatible with other finishing agents such as water repellents (®Phobotex brands), oil repellents, softeners (®Sapamine brands), and aminoplast precondensates.

Pyrovatex CP finishes are notable for

- outstanding efficiency
- no afterglow
- fastness to washing at the boil
- fastness to drycleaning
- negligible modification of handle
- good mechanical properties
- no skin irritant effects.

Application

Certain general rules must be observed when applying Pyrovatex CP finishes. For instance, we recommend preliminary trials to ascertain if dyeings and prints will undergo shade alteration or modification of light fastness. Obviously, a durable flameproof finish cannot be applied to gray goods.

Fabrics to be given a Pyrovatex CP finish must be thoroughly boiled out to remove all traces of size and to impart absorbency. Traces of size or of starch will have a detrimental effect on the finish, particularly on its durability. Moreover, starch will inhibit absorption, resulting in reduced pick-up during padding and irregular penetration of the fabric by the finishing agent.

Close attention must be paid to liquor pick-up. It makes a difference if a 25% pick-up of Pyrovatex CP (calculated on the weight of the fabric) is achieved with a liquor pick-up of 50% (500 g/l) or by one of 80% (ca. 315 g/l). In the first case the finish may prove unsatisfactory, in the second it may outlast more than 40 machine washings at the boil.

When flameproofing pretreated cotton fabrics, the liquor pick-up is usually 65–75%. Preliminary tests must be conducted on the production line padding mangle to ascertain the degree of expression and the amount of Pyrovatex CP which must be employed.

Concentration

To obtain a flameproof finish fast to both washing at the boil and drycleaning, do not use less than 25% Pyrovatex CP (calculated on the weight of the fabric). Depending on the construction, thickness and area weight of the fabric, additional Pyrovatex CP may be applied. More Pyrovatex CP must be used for light-weight than for heavy fabrics.

The larger amounts of flameproofing agent have virtually no detrimental effect on the light-weight fabrics' pleasant, soft handle. Stiffening of the fabric after treatment occurs primarily when it is dried using very high temperatures or in equipment utilizing high-speed air circulation. The best results are obtained with temperatures of 80°–100° C.

Recipe components

A Pyrovatex CP flameproof finish is applied with the addition of various other products:

1. N-methylol-triazine compounds

These act as flame retardants due to their nitrogen content, and also help to fix Pyrovatex CP.

Triazine resins have proved very suitable but, since n-methylol compounds have a detrimental effect on cellulosic fibres, their use leads to a loss of tensile strength, the extent of which is related to the amount of resin precondensate employed. Hence it is best to choose a concentration which will produce good effects while affecting fibre strength as little as possible. 100 g/l triazine resin (50% solids) would be about right.

Principal effects of increasing the concentrations of individual bath constituents in Recipe A

Constituents	Flame resistance	Handle of fabric	Tensile strength	Resistance to tear propagation	Abrasion resistance
Pyrovatex CP	appreciably improved	no effect	no effect	slightly reduced	no effect
triazine resin	appreciably improved	stiffer	reduced	perceptibly reduced	appreciably reduced
urea	reduced	somewhat stiffer	improved	perceptibly improved	perceptibly improved
polyethylene softener	reduced	softer	no effect	slightly improved	slightly improved
ammonium chloride	no effect	no effect	no effect	no effect	no effect

2. Urea
The loss of tensile strength resulting from the use of resin can be reduced by adding urea but, if too much urea is employed, fastness to washing will be adversely affected. Not more than 20 g/l urea should be used.

3. Softeners
Resistance to tearing is an important factor in the durability of fabrics. It is enhanced if selected softeners are added to the flameproof finish, improvement of abrasion resistance being an added bonus.
Polyethylene softeners are highly suitable for use with Pyrovatex CP.

4. Wetting and dispersing agents
The addition of 1 g/l Ultravon JU has been found to produce good results.

5. Catalysts
A potentially acid catalyst is needed to effect fixation of both Pyrovatex CP and triazine resins. Ammonium chloride is the best. Zinc nitrate or zinc chloride impair fastness to washing.
Magnesium chloride is NOT suitable for Pyrovatex CP.

Standard recipes
Almost every fabric requires a different flameproofing recipe, hence those given here are offered only as a guide. All the recipes were applied to a mercerized cotton serge of about 210 g/m² at a liquor pick-up of 75–80%.

A) Flameproof finish fast to drycleaning and washing at the boil:

350 g/l Pyrovatex CP
80 g/l triazine resin
10 g/l urea
4 g/l ammonium chloride
1 g/l Ultravon JU
20 g/l polyethylene softener

B) Combined flameproof and water-repellent finish fast to washing at the boil:

400 g/l Pyrovatex CP
80 g/l triazine resin
15 g/l urea
4 g/l ammonium chloride
60 g/l Phobotex f/t/c
15 g/l Catalyser RB CIBA

To prepare the impregnation bath, mix and add the constituents in the following order:

- Mix undiluted Pyrovatex CP with
- triazine resin,
- add urea dissolved with water,
- and then bulk with water to required volume, making allowance for subsequent addition of polyethylene softener or Phobotex emulsion and the catalyst.
- Add ammonium chloride dissolved with water,
- then stir in polyethylene softener diluted with water (at least 1:1) or Phobotex f/t/c with Catalyser RB CIBA in the form of a 20% emulsion no warmer than 40–50° C.

Application:

- pad at 25–30° C
- dry at 80–100° C
- cure at 160° C for 4–4½ minutes (Temperatures below 160° C result in inadequate fixation.)
- washing off: After curing, the goods must be washed off in an alkaline liquor to remove the unfixed flameproofing agent. Open width washing machines with at least four compartments should be used. The goods are washed off at temperatures of 83–96° C (180°–205° F) with the addition of 1–2 g/l soda ash in compartments 1 and 2, in hot water in compartment 3, and in cold water in compartment 4.

Technical Service and Development Department

Cibacron Courier

Covering dead or immature cotton when working with Cibacron dyes*

Cibacron dyes are used not only to dye high-quality fashion fabrics but are being employed more and more for cheap cotton staple goods. Most cheap fabrics contain dead or immature cotton which must be masked.
The Cibacron range has therefore been tested to determine the ability of each dye to cover dead and immature cotton when applied by various methods. The details are given in the relevant pattern cards.
It is apparent that coverage of dead cotton depends not only on the dye used but also on the method of application.
Fabrics containing a high proportion of dead cotton should be pad-dyed. Dead or immature cotton shows least affinity when dyed by exhaust methods, comparatively few brands then providing adequate coverage.
This lack of affinity poses problems, particularly in plants only equipped to dye by exhaust methods. Worse still, dead cotton usually shows only after dyeing has been completed, it then being clearly visible as pale, poorly dyed specks or nubs.
The presence of dead cotton can be detected prior to dyeing by means of a simple test (Goldthwait method). About 5 g of substrate are first wetted out in boiling, distilled water, and then entered into a dyebath previously brought to the boil. The liquor ratio should be 40:1, and the bath should contain 2.8% Chlorantine Fast Green BLL and 1.2% Direct Fast Red 5B (calculated on the weight of the cotton). After dyeing for 15 minutes at the boil, 2.5% common salt is added. 15 minutes later another 2.5% common salt is added. In all, the sample should be dyed at the boil for 45 minutes.
The sample is then squeezed and rinsed in two baths of cold distilled water at a liquor to goods ratio of 50:1. It is squeezed once more, then continuously stirred for 30 seconds in a bath of boiling water at a liquor to goods ratio of 50:1. Afterwards it is given a cold rinse and air dried. The hot water treatment brings out the colours, particularly green.
In the dyed sample, all the mature cotton will be dyed a reddish, all the immature or dead cotton a greenish shade.

If dead or immature cotton is present, satisfactory dyeings can be obtained by first mercerizing or at least causticizing the fabric. Practice has shown that neither boiling-out in an alkaline solution (with or without pressure) nor various bleaching treatments will of themselves result in adequate coverage of dead cotton. Only slightly better results are sometimes obtained with such methods, depending on the degree of immaturity of the cotton and the quality of the fabric as a whole.
If numerous pale specks reveal the presence of dead or immature cotton after dyeing has been completed, better coverage can be achieved by treating the dyed goods in caustic soda solution and batching them for a while. Such treatment is possible if the dyes used are fast to alkalis and acids. Most Cibacron brands will undergo no changes (for details, see pattern cards). But it is essential that the fabric be neutralized with acetic or formic acid. On no account should mineral acid be used for souring.
CIBA recommend the following procedure: The dyed fabric is padded with caustic soda solution 32–36°Tw at room temperature (not more than 25°C). The liquor pick-up should be between 60–70%. The fabric is then batched under slight tension without creasing and left for 45–60 minutes. The selvedges should not be permitted to dry. Afterwards the fabric is given a cold to lukewarm (35°C maximum) wash, soured with acetic or formic acid, and given a thorough, cold rinse. Make sure that the fabric is not finished while still acid. The pH of the final rinsing bath should be in the neutral or slightly alkaline range.
If the above precautions are taken, fabrics can be mercerized after they have been coloured with Cibacron dyes. However, it is advisable to test the fastness of the reactive dyeing in the laboratory before mercerizing or causticizing the dyed goods.
Mercerizing or causticizing after dyeing are remarkably effective means of masking dead or immature cotton. Most of the white specks disappear and the whole dyeing looks better. The final shade is deeper, probably due to fibre shrinkage. Mercerizing a dyed fabric will not, however, result in shades as deep as those obtained on fabric mercerized prior to dyeing.
Note that mercerizing or causticizing dyed fabrics may in some cases slightly impair fastness to light, abrasion, and wet treatments. For this reason too, preliminary trials should always be made.

* From «10 Jahre Praxiserfahrung mit Cibacron-Farbstoffen im Ausziehverfahren», Melliand *48* (1967) 2+3, pp. 191–199 and 314–321

M. Haelters
Technical Service and Development Department

New CIBA products

Main application	*Brand name*	*Remarks*
Dyeing and printing acrylic fibres. Suitable for outerwear, furnishing, carpet or pile fabrics made of high bulk or staple fibre yarns.	®*Deorlene Fast Orange 2GL* Original CIBA product	Yellowish orange with good build-up properties producing bright orange shades. Good fastness to light and very good fastness to wet treatment and steam even in pale shades. Good reservation of wool.
	Deorlene Fast Yellow Brown GL Original CIBA product	Particularly suitable as a basis for producing beiges, dark brown and olive shades. Very good light fastness, even in pale shades. Good build up. Outstanding fastness to wet and steam treatments.
	Deorlene Fast Red 3GL Original CIBA product	Very bright red shades with excellent build up. Together with Deorlene Fast Yellow 7GL and Blue RL makes an ideal trichromatic dyeing combination. Very good fastness to light, wet treatments and steam. Good reservation of wool.
Dyeing furnishing and outerwear fabrics made of acrylic fibres, high bulk or staple fibre yarns.	*Deorlene Fast Bordeaux 2BL* Original CIBA product	For the production of bordeaux shades and as a saddening component in brown and blue shades. Adequate reservation of wool even when applied by the one-bath method. Very good fastness to wet treatments and steam. Good fastness to light even in pale or combination shades.
Dyeing and printing textured polyamide 6.6 and 6.	®*Avilon Fast Golden Yellow G*	Greenish golden yellow. Combinable without blocking with all other Avilon brands. Good build up and coverage of physical barriness in the material. Very good lightfastness. Good wet-fastness. Clean reservation of cellulose.

New CIBA products

Main application	*Brand name*	*Remarks*
Dyeing and printing wool.	®*Lanasol Red G* Original CIBA product	Brilliant red producing purest shades, even when used in combination with Lanasol Scarlet 2R. Very high degree of fixation. High standard of fastness. Excellent washing-off properties when used in printing.
The production of deep shades on polyamide 6 and 6.6, thus augmenting CIBA's polyamide dyeing systems, i.e. ®Cibacet dyes for pale shades, ®Tectilon dyes for medium shades, and ®Avilon Fast dyes for deep shades.	®*Neonyl dyes*	Highly versatile dyes which can be used in combination without blocking. Good build up. Good coverage of physical streakiness in material when applied with Levelling Agent PAW. May be applied in a slightly acid medium. Good light-fastness. Good wet-fastnesses obtainable by aftertreating with ®Cibacet PA.
Cotton flameproofing agent fast to dry-cleaning and washing at the boil.	®*Pyrovatex CP* Original CIBA product (Circular No. 2276)	Fibre-reactive. Contains phosphorus. Produces durable flame retardant finish with negligible modification of fabric handle. Can be applied on conventional machinery. Compatible with water- and oil-repellents, ®Phobotex water repellents and extenders, ®Sapamine softeners, and ®Lyofix aminoplast resins.

A CIBA product for every dyeing, printing, and finishing process!

Polyamide carpet materials

Pre-scouring	®Ultravon WCA, JU
Yarn and piece dyeing	®Tectilon dyes applied with Leveling Agent PAW or ®Cibacete dyes with ®Univadine CD or ®Albatex POK
Differential dyeing	Selected dye brands and combinations for all fiber blends, including cationic dyeable types
Continuous dyeing	Processes and selected products for solid color and differential dyeings
Space-dyeing	Selected dyes for the most widely used types of carpet fibers
Carpet printing	®Cibalan and ®Avilon Fast dyes applied with emulsion thickening to eliminate flushing
Eliminating frosting	®Cibaphasol AS
Improving wet-fastness and reserving polyamide when dyeing jute	®Cibatex PA
Soil release and anti-static finishes	®Sapamine NP
Imparting soft hand	Sapamine brands