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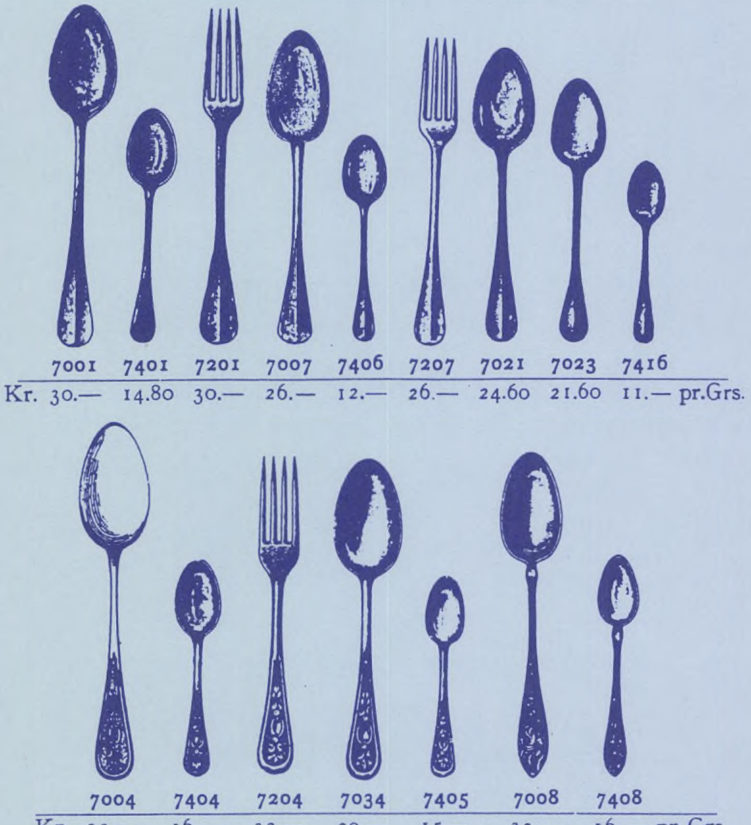

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Industrial Research and Technical Proficiency

Swedish Industry in the Early 20th Century*

I Introduction

Economic and industrial growth rates in Sweden between the mid-19th century and the 1970s were among the highest in the world, and during the decades from the 1870s to the time of the First World War, industry increased by approximately 5 per cent per annum.[1]

To a fairly considerable extent, as I shall argue below, this can be regarded as a result, firstly, of an institutionalized technical education which provided industry with the technical competence necessary in its day, and secondly, of primitive forms of industrial research which were adequate at the time. The evolution towards "modern" industrial research laboratories and departments, which in Sweden as in most other industrial countries emerged as a general phenomenon during the interwar period of the 20th century, must be seen in the context of a continuous developmental process. This implies a view of Swedish industrial production at the turn of the century slightly different from the one manifested in certain fairly recent sociological and historical works (see below).

Another relevant aspect in the context of Swedish technical proficiency at the time is the debate among Swedish economists and economic historians over the Swedish industrialization process. Thus, there is a consensus that it was the last decade of the 19th century that saw the "modern" Swedish industrial society emerge; but what was the economic background or cause of the industrial development of the 1890s? An earlier more or less established view

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on the topic - shared by Heckscher, Gårdlund and Jörberg for example - holds that Sweden was industrially and technologically an undeveloped economy in the 19th century and that Swedish developments before 1890 were merely a response to changes abroad.

However, another view, more recent and more convincing, underlines the importance of "internal dynamics", in which the 1820s already marked the initial phase of an increasing industrial production orientated particularly towards the domestic market. This development culminated in the 1850s and 1860s in a more general emergence of factory industry in certain branches. In that perspective the export trade of the 1850s and 1870s becomes at once an outlet of and a supporting factor in the growth process.[2]

Although it seems proper to stress that the two views of Swedish industrial development are complementary to one another, the results of certain studies - for example of Swedish participation in international industrial exhibitions during the middle years of the 19th century, notably those in Paris in 1855 and London in 1862 - support the view emphasising internal dynamics and the Swedish technical contributions to that process.[3]

Consequently, the Swedish industrial growth process during the 19th century must be regarded as a continuous one, and it is quite clear that from at least the middle of the 19th century, many Swedish firms in the mining, metallurgical and engineering industries were run by owners and managers who were acquainted directly or indirectly with the technological frontiers of their industries through their network relationships, especially those with the leading Swedish technical institutions.

Technical competence and primitive forms of laboratory and research work existed well before the appearance on the scene of the Swedish "genius" industries, so-called, towards the end of the 19th century. Although developments in these areas accelerated at the turn of the century, the new - i.e. "genius" - industries being in the vanguard of the process, Sweden's organization of industrial production conforms to an international pattern of which Germany and the United States were the leading exponents.

The growth and structure of Swedish industry during the 19th century and the early part of the 20th are presented in section II below, while section III considers the factors of technical proficiency and research organisation in industry. The availability of engineering competence is discussed on a general and macro level and in an international perspective, but managerial and laboratory organisation is considered at micro level as well. Nine Swedish firms have been selected for closer study. Five of them belong to the category of "genius" industries - *AGA, ASEA (ABB), Alfa Laval (Tetra Laval), Ericsson* and *SKF* - while the other four had their genesis in the middle of the century.[4]

Section IV, the final one, is the place for certain closing remarks and the drawing of conclusions. Reference is made at this point to the debate over the two engineering "ideals" and the views expressed in the literature concerning the status of research and proficiency in Swedish industry at the time.

II Growth and Structure of Swedish Industry

Availability of capital, of workers for the various occupational levels, and of markets - factors which are created daily in an industrial society - constitute the prerequisites of modern industrial production. During the late 18th century and throughout the 19th, these prerequisites were created in diverse ways by nations like England, France, Germany, USA and Sweden.

Of course, it is very difficult to establish exactly when a process of industrialization starts in a specific country, but it is fair to say that Sweden's progress towards industrialization was well advanced by the middle of the 19th century. The 1850s were also the first decade in which Sweden experienced a trade-cycle boom originating in the industrial sector, viz. the wood and timber industry and its exports.[5]

But manufacturing industry's share of the GNP was small, and this was still the case during the boom of the 1870s. The characteristic economic feature of the 1870s was rising investment in all sectors of industry and in the infrastructure (the railways).

From the 1880s onwards Swedish manufactured products became more highly processed and of higher quality. Exports were more differentiated and goods such as pulp, paper and engineering products, notably from the electrical engineering industry, became important.

As was pointed out in the Introduction, it is from the last decade of the century onwards that we can speak of a "modern" Swedish industrial society. Thus, the boom of the 1890s, which formed the Swedish economy's third period of growth and expansion in the second half of the 19th century, substantially increased the proportion of production and occupations represented by industry. Industrial production of consumer goods for the domestic market increased sharply, and the expansion was of the same order of magnitude as in capital goods and exports.[6]

The new Swedish export product of the 1890s, iron ore, meant that the export pattern was again affected, but as in the mining and iron industry, the technical and management characteristics of this product were much more complex than those of sawmill products, for example.

Unfortunately no detailed studies of the relative importance of science-based and knowledge-intensive industries during the 19th and early 20th centuries are in existence. But such studies do exist in respect of the size-structure of Swedish industry as a whole from the 1870s. For earlier periods it will suffice to emphasize the obviously skewed size-structure of manufacturing industry. The dominance of large-scale enterprise is evident, most notably so from the 1870s onwards. By the turn of the century, 50 per cent of all labour in Swedish industry was employed in establishments with more than 500 workers.[7]

Thus, it is clear that big firms dominated Sweden's industrial development. As will be shown in section III below, by the turn of the century these firms, represented here by the selected "genius" enterprises in particular, had highly qualified engineers in senior and managerial posts, had established industrial laboratories, and in some cases had already founded embryonic R&D departments.

These firms had also established specialized industrial production, vertically integrated from raw material to finished product in some cases, along with an international marketing organisation. It is also worthy of remark that the firms selected were of considerable importance and occupied a position of leadership in Swedish industry at the turn of the century, a position which in large measure they still enjoy. This is most true in the case of the "genius" industries, but it also applies to some examples of "older" industries such as *AB Sandvik*.

III Industrial Research and Technical Competence

The title of this paper, like this section heading, implies somewhat clear-cut categories, especially in the case of "industrial research" with its connotation of organized and institutionalized industrial R&D, i.e. Research and Development. But the terminology presents difficult problems of both a semantic and a scientific nature when it is related to industrial performance in the 19th and early 20th centuries.

As was pointed out above, the process of industrial growth has to be viewed as a continuously evolving process intimately linked with the development of "technical competence" and improvements of manufactured products and processes. This very complex development also has its national features, as will be noted below. The first question to be settled, then, is what is meant by the expression "industrial research"?

While the word "industrial" is clear enough, the term "research" has a number of meanings. Kendall Birr discusses the terminological difficulties in his book **Pioneering in Industrial Research**, dealing with the history of the *General Electric* research laboratory. He considers *inter alia* the common distinction between "fundamental" and "applied" research, where the former seeks to enlarge our scientific knowledge and the latter to explore technology by means of scientific methods and principles. In the course of these deliberations he touches on the laboratory, the arena of institutionalised research: "Industrial research laboratories have engaged in both kinds of investigations, but they are quite naturally concerned primarily with applied research."[8]

However, examining the kinds of activity conducted in "research" laboratories makes him realize the "difficulties and follies" of making narrow definitions; "the term 'research' covers a wide spectrum of scientific activities. /---/ any attempt to distinguish fine gradations in a research hierarchy has little basis in reality since there is little or no agreement on the boundaries between the various types of research." This is based on a realization of how laboratories have sponsored activities ranging from fundamental research to quality control and routine testing as well as production control. Birr concludes: "In the final analysis, industrial research as it developed in the late nineteenth and twentieth centuries involves at least four elements. First, it is nearly always organized research; /---/ Second, industrial research uses scientific methods and scientifically trained personnel. Third, industrial research is concerned with the natural sciences and technology and excludes such things as the social sciences or market research. Last, the investigations carried on in industrial research laboratories, whether they be fundamental or applied research, are connected in one way or another with industry and are directed primarily toward improving technology and maximizing economic satisfaction."[9] From this conclusion we extract the common denominator that research should be conducted in organised form of one sort or another by qualified scientists and/or engineers/technicians.

The importance of industrial research in the growth process was realized later on in the 19th century by all the industrialized nations - but the form that realization took bore the impress of its national characteristics. To quote Kendall Birr again: "Individual countries have had a wide area of choice in how they might utilize and administer industrial research; none could escape the consequences of neglecting it."[10]

What is of greatest interest to us is how - and when - the individual firm embarked on industrial research. The leader in this development was Germany, and it was in the German dyestuffs industry that the "in-house" R & D laboratory was invented in the 1870s.[11] According to Schmookler it was in the Germany of the 1860s that business enterprise began "/.../ to consider that science had matured enough to make its systematic cultivation profitable at the level of the individual firm."[12] Jürgen Kocka believes that by the 1850s industrial research laboratories were already functioning in Germany in the areas of metal products, chemicals and electrical engineering. These laboratories also habitually maintained close contacts with academic and research departments in the natural sciences and technological fields at universities and technical institutes.[13]

The timing here is obviously somewhat imprecise because of the differing approaches of scholars, but our discussion above shows this to be of minor significance. The essential point is that the industrial research laboratory was developed in Germany - and that a sizeable proportion of industrial research was concentrated in the laboratories of the large German corporations. Birr holds that "From about 1900 to 1930, Germany was quite clearly the leading industrial research country in the world"[14], but it seems justifiable to extend that period back into the 19th century, since his conclusion was based essentially on what was going on in the large German firms such as Bayer, BASF, I.G. Farben, Krupp, A.E.G. and Siemens (although other organizational forms of research, such as the *Kaiser Wilhelm Gesellschaft*, founded in 1911, were brought into the reckoning as well).

Bearing these facts in mind, the proposition that the "classical" industrial research laboratory was born in the United States[15] raises again the questions of definitions and explanations.

However that may be, separate industrial research departments were being set up by the major American industrial concerns around the turn of the century. Alfred Chandler has pointed out that even as early as the 1890s, some of the new integrated industrial enterprises were beginning to rely on their specialized research departments to maintain their dominant position. Eastman Kodak established its experimental department in 1896, with managers trained in chemical engineering at the M.I.T. and other universities. Other less technologically sophisticated industries had research departments too, with their own laboratories distinct from those for testing products and controlling processes. "By the first decade of the new century", corporations like Westinghouse, General Electric, DuPont and McCormick Harvester (International Harvester) "all had extensive departments where salaried scientifically trained managers and technicians spent their careers improving products and processes."[16]

Obviously the characteristic feature of the American industrial research laboratory which justifies its being called "classical" is that it was a separate organisational entity within the firm, with highly qualified - and highly salaried - engineers/technicians/scientists engaged in industrial research.

General Electric, founded in 1892 as a merger of Edison's General Electric Company of 1889 (with a history going back to 1878) and the Thomson-Houston Company (1883), has been considered something of a pioneer case in the history of American industrial research - note the sub-title of Birr's work - and there is no reason for doubt in this regard.

The history of the General Electric research department goes back to the laboratories of Edison and Thomson in the 1880s. But it took almost a decade after the merger of 1892 before it was felt important - and profitable - to establish a laboratory exclusively devoted to original research. This was the General Electric Research Laboratory (1901).[17] Its beginnings are said to have been humble and its functions ill-defined. This was probably one of the reasons why Willis R. Whitney, the highly qualified chemistry instructor from M.I.T. who became the Laboratory's first director, was dubious about accepting the appointment when it was offered him.

However, the Research Laboratory developed so successfully that when it entered the post-First World War period, its standing was very different from what it had been twenty years earlier. It was now a well-established institution of the highest conceivable scientific and technical reputation, with excellent personnel and a well-organised system of administrative, financial and indeed moral backing from General Electric's top management.[18]

The 1920s became the seedtime for most of the American industrial laboratories.[19] But some of the more important laboratories had been founded well before the War, as we have already noted: it was interest in organised research that became more general and active after the War.

As we have pointed out, developments in Germany manifested themselves earlier than in America. In Sweden they seem to have followed some kind of a middle course.

It was in the Swedish "genius" industries especially that industrial research laboratories were founded and developed, but events in the older mining and manufacturing industries too show a pattern in which laboratory work was a vital factor. Large-scale industry, both new and old, was managed to quite a considerable extent by technically well-educated engineers; and in the "genius" industries at least, a substantial proportion of the staff likewise had formal technical qualifications.

Although it was from the 1920s onwards that developments accelerated in Sweden, in many cases the features of managerial capitalism and what Chandler called "the visible hand" can be discerned in large-scale industry well before the First World War. Swedish industrial development conforms well to the German and American pattern in terms of technical competence, industrial research and organisation; and again, developments in these respects must be seen as a continuous process in which national traits must not be overlooked.

That "everything new" in Sweden in these respects was imported and occurred only after the First World War is simply not true. In saying this, of course, we are not denying the international influences brought to bear on events in Sweden, for example by Frederick Taylor and "scientific management". But the latter, when its various forms are considered, was as much a German or French idea from the late 19th century and essentially a general pattern of industrial organization in the western world - a pattern to which Swedish development conformed.

The Swedish Experience

The predominance of large firms in Swedish industrial growth and performance from the 1870s onwards has been pointed out in the foregoing. It is also in these firms, to quite a considerable extent, that we find the qualified engineers who graduated from Swedish technical universities, institutes and colleges.

As early as about 1830, Sweden had two technical schools, viz. the Technological Institute (1826) in Stockholm and Chalmers (1829) in Gothenburg, both of which developed into technical universities. In formal terms this happened in 1877 in Stockholm, whose institute became The Royal Institute of Technology (*Kungliga Tekniska Högskolan*, KTH), and not until 1937 in the case of Chalmers; but in real terms Sweden had two technical universities during the 19th century. For example, the report of a committee of enquiry into lower technical education in Sweden in the early 20th century declared that the older Swedish technical institutions, i.e. the two above-mentioned and the Falu Mining School (which was amalgamated with KTH in 1867/69), could be described as "higher technical institutions" in the middle of the 19th century.[20] Also in the middle of the 19th century, four technical secondary schools or colleges - a fifth one followed about 1900 - had been founded with a view to supplying a complete technical education at somewhat lower occupational levels or at management level in smaller-scale industrial firms, at the same time providing qualifications for entrance to the higher institutions. As examples of these technical schools, to which reference will be made later in this paper, we may cite those in Malmö and Örebro, founded in 1853 and 1857 respectively.

It has been calculated that in the late 1890s, Sweden's stock of practising highly qualified engineers (i.e. educated at KTH or Chalmers)* was about 2000, and that the number of such engineers at the time of the First World War was just under 3500. A rough estimate of the total number of engineers with formal qualifications in Sweden at that time gave a figure of almost 9000 practising engineers.[21] Some of these were employed in the public sector, but most were in the private sector. For example, of the engineers graduating from KTH, Chalmers and the technical secondary schools between 1880 and 1910, 60-70 per cent were in the private sector after about fifteen years in employment.[22] This is similar to the occupational distribution of the members of The Swedish Association of Engineers and Architects (*Svenska Teknologföreningen*) around 1910.[23]

The committee of enquiry cited above, covering about 3600 practising engineers in 1908 with technical qualifications from the Swedish schools above-mentioned and including 10 per cent with a foreign technical education, showed that 60.5 per cent were employed in the engineering or manufacturing industries and 15 per cent in the mining industry. The remaining 25 per cent were either engineering consultants or the like (9 %), or else employed in the public sector (railways, telecommunications, etc; 12 %) or by the private railways (4 %).[24]

Among the facts remarked on by the committee were that more than half (54 %) of the engineers studied were employed in what were called "true" engineering and allied industries, and that there was one technician/engineer to every factory - a figure similar to that found in the paper and pulp industry, which was considered separately.[25]

I have pointed out elsewhere that the German pattern of education was the blueprint for institutionalized technical education in Sweden from the middle of the 19th century onwards, but also that the total density of engineers with formal technical qualifications was lower in Sweden than in Germany.[26]

However, there are other considerations. The importance of large-scale industry in Swedish growth and performance is one. It should be borne in mind too that highly qualified engineers in industrial firms were employed not only in laboratories, for example, but also, and to a higher degree than the average figure suggests, in managerial positions. Moreover, the social

* their Swedish title "civilingenjör" is transcribed below as "civil engineer"

prestige attaching to a technical education was high: the social background of students at KTH and Chalmers in the early 20th century (1902/04) was very similar to that of students at the classical universities of Lund and Uppsala.[27] From all this it seems a not implausible inference that the competence factor and its availability *via* qualified engineers made an extremely significant contribution to the success of Swedish industry.

This having been said, it is important to study developments in these respects at the level of the single firm, and also to examine how industrial laboratory operations evolved into institutionalized industrial research.

We shall focus first on the five selected examples of Swedish "genius" industries, then similarly scrutinize the development of certain "older" industries founded around the middle of the century. We shall concentrate on the formal technical proficiency existing in the firm and on the development of industrial research and organization. The sources are of secondary type (monographs), which means of course that the quality of the material varies.

The "genius" industries

The so-called "genius" industries of Sweden's industrial development were founded towards the end of the 19th century or during the first decade of the 20th, and after the passage of a hundred years they still figure among Sweden's dominant, top-ranking industries in both a national and an international perspective.

The term "genius" refers to a number of specialized engineering industries which were based on Swedish inventions and made their marks fairly quickly as large exporters. *Separator* (*Alfa Laval, Tetra Laval*), *AGA* and *SKF* are the most prominent of these, but *L.M. Ericsson (Ericsson)* and *ASEA (ABB)* are normally considered to belong to the "genius" group as well, even though the telephone was not a Swedish invention and it was some time before the high-voltage engineering firm of *ASEA* became a prominent exporting firm. As well as these firms there were others founded around the turn of the century which belonged to the "genius" group but did not develop into large-scale ramified enterprises.[28]

L.M. Ericsson - just *Ericsson* from 1981 - is the oldest firm in the group. The world-renowned Swedish telephone industry was brought into being by Ericsson and H.T. Cedergren, two individuals of quite disparate educational backgrounds. Whereas the former had no formal technical qualifications, the latter was a highly qualified engineer.[29]

It was in the mid-1860s that Lars Magnus Ericsson began receiving practical technical training at a Stockholm telegraph workshop enjoying financial backing from the public telegraph authorities (the Telegraph and Telecommunications Board) for its experimental work and for its provision of vocational education for promising young "industrialists". Ericsson was also awarded a state-assisted grant for studies abroad, and he spent the years 1872-1875 chiefly in studying the electrical engineering industry in Germany and Switzerland, spending a fairly lengthy period with one of Europe's leading electro-mechanical firms, *Siemens & Halske* of Berlin.

On returning to Sweden he relinquished his former employment and, along with a friend from his previous job, started up the firm of *L.M. Ericsson & Co* in the spring of 1876. Twenty years later the firm was converted into a joint stock company and from that time onwards it was managed by Ericsson alone.

Bell's invention of the telephone had been presented to the general public for the first time at the Philadelphia world exhibition of 1876. When news of the invention and its patenting reached Ericsson in 1877, its potential became apparent to him. The problem, however, was the international Bell concern and its virtual monopoly position, which influenced telephone rates and therefore the scope for proliferation of the telephone in Sweden. It was Henrik Tore Cedergren who reacted most vigorously to the situation, founding the *Stockholms Allmänna Telefonaktiebolag* in 1883 under the slogan "a telephone in every Stockholm household" and basing its operations on telephone equipment from L.M. Ericsson.

The *SAT* and *LME* firms developed in close concert: it was important to Cedergren to have access to telephone equipment not controlled by the Bell corporation. The two companies amalgamated in 1918 as *Allmänna Telefonaktiebolaget LM Ericsson*, but by that time the two founders had retired from their positions as managers many years earlier.[30]

Cedergren is said to have been the corporation's driving force. Whereas Ericsson was more of a "self-made" man of humble social background, Cedergren was an educated engineer of middle-class background. He studied at the Technological Institute in Stockholm - *KTH* - from 1872 to 1875, graduating as a civil engineer, i.e. a highly qualified non-military engineer. Ericsson is said to have been suspicious of theoretically-educated personnel in his firm, and production during the early years was of a craft nature.[31] It was a long time before highly qualified engineers (and economists) were employed at *LME*. But Ericsson was not averse to novel approaches to production technique. He had been introduced to the new American concept of large-scale mass-production during his *Siemens & Halske* period[32], and in 1885 the cutting mill was installed at the Ericsson firm.[33] Ericsson and Cedergren went to the United States together in that year in order to study the development of the telephone industry there.

It is fair to say that Ericsson was not on the whole a revolutionary innovator. The revolutionary technical inventions were of American origin - Bell's telephone and Schribner's multiple system for efficient routing of calls at the telephone exchange (1879) - but meticulous precision-engineering techniques enabled Ericsson to develop these inventions successfully. *LME*, often in close concert with *SAT*, systematically borrowed American technology during the 1880s and so caught up with it. With respect to design technique, however, the Swedish firm was ahead of the Americans.[34]

SAT's philosophy of personnel recruitment was quite different from that in force at *LME*. From the outset Cedergren employed highly qualified engineers capable of assimilating new technology fairly easily. By the mid-1880s (1886), *SAT* had 64 male employees, eight of whom were graduate engineers.[35] The high level of technical proficiency and knowledge at *SAT*, *LME*'s biggest customer, produced considerable spin-off benefits for the L.M. Ericsson firm as well.[36] By the turn of the century *LME* had become a "large-scale" industry[37], and by the middle of the first decade of the 20th century its personnel numbered about 1500.

As regards how the organisation of industrial research evolved, the early laboratories focused on checking the results of the designer's ideas. Various design alternatives would be successively tested. These would be followed by various "field-tests" in which "confrontation with reality" determined the final design decision.[38]

Despite his lack of enthusiasm for formal technical competence when recruiting personnel, L.M. Ericsson realized from the outset the importance of technical expertise as a factor of production. He understood from his experience as a production manager that good design was a prerequisite of success in the telephone manufacturing field. But it was a long time before technical and working functions were organised separately from other functions. The personnel of the industry often covered the whole range of functions, functions which in later days required separate specialists. It is said that it was only towards the end of the decade 1910-1920 - after the merger of 1918 in fact - that the idea of a separate organisation for technical developmental work was conceived.[39]

In 1925 a general laboratory was established along with various special departments. A drive to reinvigorate the company's technical resources was launched, and a large number of recently-graduated and highly qualified engineers were brought in. Engineers already occupied positions as section and divisional heads, but now engineers were appointed to administrative posts as well.

In the early 1930s the head office was thoroughly reorganized. As well as the separate Technical Department we now find a separate Department for Research and Development.[40]

Gustaf de Laval's invention of the milk-separator, displayed to the public for the first time in 1877, was the genesis of one of the true Swedish "genius" industries, **AB Separator** (1883), renamed *Alfa-Laval AB* in 1963 and *Tetra-Laval AB* in 1992. Both invention and firm quickly acquired an international reputation.[41]

De Laval was a highly qualified engineer and a very talented inventor. Although the principle of the separator as such was known, the invention of the milk-separator was his. Gustaf de Laval graduated from the Technological Institute (*KTH*) in 1866, with maximum grades in mechanical engineering. He went on in 1867 to study chemistry, physics and mathematics at Uppsala University, receiving his doctor's degree in 1872. In 1886 Gustaf de Laval was elected a member of the Royal Swedish Academy of Sciences (*Vetenskapsakademien*), as well as of the Royal Swedish Academy of Agriculture and Forestry (*Lantbruksakademien*).

De Laval collaborated for some years with O. Lamm, who had likewise had an advanced education and ran an engineering firm. They founded the separator firm jointly in 1883. As a result of disputes within the firm however, Lamm left the company in 1886 and J. Bernström was appointed as the new managing director. It is to him that the credit belongs for *ABS* having built up an international sales organisation, founded an American subsidiary company (The de Laval Separator Company, *Lavalco*) in 1885, and become an early example of a multinational enterprise.

It is beyond doubt that Gustaf de Laval was a technical inventive genius, but he lacked managerial and marketing abilities. A good example of his many ideas in the fields of mechanical engineering, chemistry, metallurgy and electro-technology was the invention of the steam turbine, resulting in the setting up of the firm *AB de Lavals Ångturbin* (The De Laval Steam Turbine Co) in 1892; but most of his projects turned out to be economic failures.

De Laval's faith in Bernström was such that he withdrew from direct management of *ABS* in the late 1880s. By the early 20th century (1903) at the latest, *ABS* had become purely a manager-controlled firm as an indirect result of turbulence in the ownership and finances of the company. By the time of the First World War, the *ABS* factories in the Stockholm area had about 1000 - 1200 manual workers as well as engineers and other staff. In total, i.e. taking into account all the firms comprising the concern, *ABS* employed more than 5000 workers and staff by 1915.

What general statements can be made about technical proficiency and industrial research at *AB Separator*?

As regards technical competence we have detailed above the very high technical qualifications of both de Laval and Lamm. Gustaf de Laval considered himself a technician and inventor in the service of the Swedish nation![42]

His early experimental work commenced during the 1870s in a Stockholm firm producing stearine candles. Along with a blacksmith's shop and an engineering shop, this firm (*Liljeholmens stearinfabrik*) also had a chemistry laboratory.[43] In the early 1880s de Laval set up an experimental workshop to which he gave the name of the "Machine factory".[44]

He continued his experimental work after the founding of *ABS*. Having successfully developed the separator, he concentrated his activities from the 1890s onwards on the other technical specialisms specified above, setting up also a separate technical development firm of a more general type. In 1891 he established a kind of breeding ground for inventions. In this way he is said to have realised a plan he had cherished since the middle 1880s: "As soon as my position is strong enough", I want to establish "a kind of bank" where inventors can get their designs "sifted" until ready to be presented to some capitalist.[45]

By the middle of the 1890s, the technical firm or agency, which was equipped with experimental laboratories and workshops, employed more than a hundred people. About seventy of these worked either at the de Laval head office, in the drawing office or in the experimental laboratory. About 25 of the technicians had formal engineering qualifications. Apart from the de Laval engineering office, where the drawings were made, the Experimental Engineering Laboratory, the Chemistry Laboratory and the Experimental Electrical Laboratory may be cited as examples of the laboratories.[46]

From the financial standpoint, of course, these experimental and research activities produced very little return. But the idealistic results were probably great, particularly because of the close relations existing with the Stockholm technical university. Many young men who started their careers as design technicians, for example, went on to enjoy successful engineering careers, as did E. Danielsson, *ASEA*'s chief designer, while some became professors in the engineering sciences at *KTH*.[47]

The information available concerning formal technical competence at *AB Separator* prior to the turn of the century is somewhat unclear. However, we do know that the production plants in Stockholm were directed by foremen without formal technical qualifications from 1882 to 1889, but that in 1899 a highly qualified engineer was appointed director of these establishments.[48] In 1906 he was succeeded as chief engineer director by another civil engineer, E.A. Forsberg, a *KTH* graduate who had formerly been head of the drawing department at *ABS* and was destined to be an influential figure in the history of Swedish industrial organization.

It is about this time that a picture emerges of *ABS* as a specialised enterprise with few equivalents in the Swedish engineering industry in terms of organisation and equipment.[49] The nineteen production units were headed by foremen, who worked under the direction of department heads. The managements of the five main departments were subordinated in turn to the chief general manager, who also had responsibility for the drawing office, the testing laboratories and the accounts department.

The *ABS* "automatic shop", as it was termed, was described in these words: "From the moment the processing of the raw material begins until the finished manufactured product drops into a waiting box, it is untouched by the worker's hand." Thus, the level of mechanization was very high, and each separator made the following peregrination: checking of the various parts by a specialised inspection department, assembly department, final inspection, painting, control dairy (where the separator was tested with milk), storing and packing. Gårdlund says that this mechanization of the *ABS* production process had developed very quickly after the Alfa patent was acquired in 1889, and the output of hand-separators was raised to 5000 - 10000 units per year. Developments at the American *Lavalco* subsidiary - where 800 men produced the same output as 1200 men in Stockholm - was particularly important.[50]

Perhaps it is worthy of remark that mechanical modernization was initiated before *ABS* obviously began employing highly qualified engineers as production managers: it should be remembered that the head of production was a foreman with no formal technical qualifications. But the engineers employed during the 1890s had special development projects to handle as well as other tasks of a staff character. Evolution towards a highly-mechanized workshop - an exemplary one, according to Gårdlund, with one chief engineer and five section engineers - did not start until the turn of the century.[51] From that time on, highly qualified engineers also managed the production process. The technical collaboration that evolved between *ABS* and *Lavalco* gave the Swedish firm the leading role in separator design while the American subsidiary led in production technique. Thus, the outlines of the modern organization appeared during the first decade of the 20th century.[52]

By 1903, *ABS* had 11 engineers, of varying qualifications, on its staff, a number which ten years later had increased to 19. As well as these engineers the firm had about double that number of staff employees of other kinds in addition to the manual labour force.[53] The figures are indicative of the trend towards rationalization of the firm. A dynamic building-up period of *ABS*, starting around the turn of the century, may be said to have come to an end by the time of the First World War. New products of high technical quality, such as milking machines and separators for industrial use, were developed subsequently. These products were developed successfully in the framework of the pre-existing organization of design, production and testing. Thus it was not until 1948 that a special department for R&D was established at *ABS*.

The third of the selected Swedish industries of the "genius" group to be discussed is **ASEA - Allmänna Svenska Elektriska AB** - which became *ASEA Brown Boveri, ABB*, following amalgamation with its old Swiss competitor in 1988.

The firm *Elektriska Aktiebolaget in Stockholm*, based on inventions and patents (especially the dynamo) by the engineer J. Wenström, was founded in 1883 by L. Fredholm, a former banker with large technical interests. In 1890 the firm moved to Västerås with its main production unit. In 1891, a year which coincided with the foundation of *Brown Boveri*, the name was changed to *ASEA*.[54] By that time Wenström, who was a consultant to the firm, had made significant improvements in the field of high-voltage technology, introducing a complete system of three-phase alternating current.

The "pioneering years", which lasted until about 1890, were a period characterized by limited financial resources but also by solid technological and market build-up. The dominant features of the next decade were an explosive growth of national and international markets and important progress in three-phase technology. But because ASEA had been drawn into the ambit of Gustaf de Laval and his financial affairs, it also brought turbulence of ownership. However, a financial and organizational reconstruction of ASEA was carried out in 1903. Although engineers and the technical considerations they represented had always been very important and influential in the firm's production and management, this characteristic became even more prominent after the turn of the century. ASEA became an enterprise run and led by managers, a state of affairs to which further emphasis was lent when ASEA shares began being sold on the open market in 1911 and ownership became further dispersed as a result. Although ASEA was comparatively small in an international perspective at that time, its technological standing was on an equal footing with that of the leading electric giants such as General Electric, AEG and Siemens.

Like its forerunners in the 1880s, ASEA was dominated by technicians from the outset. Technical competence was of a very high standard, and the firm's network relationships with the leading Swedish technical institutions were very close in numerous ways. Technical and organizational ideas were also fed back by various routes from Swedish engineers on job-experience visits to or employed by leading international industries, particularly in Germany and the United States.

Fredholm studied the gas and electric lighting systems of England and Germany in the early 1880s and became convinced that the future rested with high-voltage technology.[55] In 1881 he appointed Georg (Göran) Wenström, younger brother of Jonas and a graduate civil engineer, to act as technical director of certain tests of electric lighting designs.

The two brothers kept in close touch with international developments: in 1881, for example, Jonas visited the exhibition in Paris where the latest technological innovations and novelties were on display. In 1889 Georg received a grant from The Swedish Ironmasters' Association (*Jernkontoret*) to study continental developments in electric power-transformation. Georg Wenström was production manager of *Elektriska Aktiebolaget*, and when *ASEA* was established in 1891 he became its managing director.

ASEA set up a section specifically for design in 1892. Jonas was employed by ASEA in that year, but continued to act largely as an independent inventor.[56] The real chief designer was the highly qualified engineer Ernst Danielsson mentioned earlier. The latter had completed his studies at *KTH* in 1887 and had worked as an assistant to Georg Wenström. In 1890 he went to the United States for two years of practical studies. He was employed at The Wenstrom Consolidated Dynamo and Motor Co in Baltimore and also worked at the Thomson Houston Electric Co.[57] During 1892 he was production manager at ASEA, managing the firm's technical development as well during that year, jointly with Jonas Wenström[58]. In 1893-95 he was technical manager. He was employed by Gustaf de Laval as chief designer during the period 1895-1900 but returned to ASEA in 1900 as technical director. He retired in 1903 for health reasons, although he remained as a consultant to ASEA until 1905. One of the notable events during his time at ASEA was the installation of what was probably the earliest electrified rolling-mill in the world at *Hofors Bruk* (Hofors ironworks) in 1894.

As we have already remarked, a significant event in ASEA's history occurred in 1903, when ASEA became a "Wallenberg firm" and Sigfrid Edström was appointed as managing director while Georg Wenström remained on the ASEA board (until 1910).

Edström too was a highly qualified engineer who had graduated at Chalmers in 1891 and at Zurich Technical University in 1893.[59] He was employed by Westinghouse and General Electric in the United States during the period 1893-97 and spent the following three years with the Zurich tramways. It was during these years that the Zurich tramways went over to electric power transformation. As director of the Gothenburg tramways in 1900-03 he managed their conversion to electric power. Edström became managing director of ASEA in 1903 and remained in post for thirty years. As observed above, it was during his era that the firm was thoroughly reorganized and the expansion of ASEA into a large concern was accomplished.

What is to be said about the ASEA organization, in terms not only of industrial research especially but also of other aspects of technical competence, and of its organization of staff and workers - before as well as after the reorganization of the early 20th century?

The organization of industrial research conforms closely to a general Swedish and international pattern. Thus research activities, consisting at first of private individual experimentation and laboratory work, moved on to assume an organized form within a period of ten years. Qualified engineers were employed, and network relationships (with *KTH* for example) were very close, at least at managerial level. Industrial and technological knowledge kept abreast of international developments.

The Wenström brothers grew up in a very technical milieu. Their father was an engineer with a consulting engineering agency in Örebro. He was well known as a designer of blast furnaces, steel and rolling mills, hydraulic turbines, and so forth.[60] Jonas maintained close contacts with his father and worked in his agency. This continued even after he became employed at ASEA. He had also had opportunities for experimental and laboratory work at the engineering works in Arboga (about 60 miles west of Stockholm), which was associated with the Stockholm firm *Elektriska Aktiebolaget*. It is said that at this factory, which was managed by Georg Wenström, Jonas and a number of other engineers later employed by ASEA enjoyed opportunities for full-scale experimentation. There can be little doubt how important these circumstances must have been for subsequent design activities.[61]

As was noted above, ASEA established a special design section with several engineers in 1892. The firm was now acquiring a strong position, most notably in the high-voltage field. Standardized series of machines for alternating electric current and transformation were designed and successively improved as methods of calculation and experimentation improved. It is also worthy of notice that in the late 1890s ASEA established a close collaboration with the de Laval steam turbine company in the field of turbo-generators - an early and internationally-remarked example of close collaboration between a producer of steam turbines and an electrical firm.[62] The new alignment of management brought a tightening-up of organization, while organization became regarded as an instrument of management.[63] Even prior to the reorganization of 1903, the outlines of a "research" organization are discernible by implication behind some of the titles within the ASEA central production unit in Västerås.[64] As well as the managing director (G. Wenström) we find the "technical director" (E. Danielsson), the "engineering office" under the engineer A. Lindström, the "testing shop" and the "drawing office". The organizational structure of 1908 can be thought of as the final shape attained under the reorganization. At the top of the structure we find the board of directors, the managing director and a separate technical manager for the whole organization.[65] The patent department, too, is at the head office.

Further down the structure there are seven sections, including the engineering shop and the foundries. Of specific interest in relation to industrial research is the first section, the electrical shop, where the posts of section head and general director are held by the same individual. There is then a hierarchical organization at nine levels - from "Orders and Dispatching" at the bottom to "Design" at the top. In between there are separate departments for calculating, testing and costing.

It may fittingly be said that ASEA was a successful representative of the ideas imbuing the consciousness of the Swedish and international engineering industries of the day, viz. hierarchical organization along with the concepts of specialization, high-volume production and efficient organization (integration).

ASEA made further changes in its organization in 1915 and 1920. At the earlier of these dates, for example, a separate materials laboratory was established at the main ASEA plant in Wästerås[66], but what is remarkable is that it was not until the organizational scheme of 1936 that a separate research department - the "Department of Research and Installations" - was established.[67]

ASEA's successful development over the years is manifestly attributable to its long-established technical proficiency, personified by its large staff of qualified engineers and its well-trained labour force; even as early as in the late 19th century, the internal training of engineers and technicians was considered an essential conception at ASEA, and so it has continued to be.

AGA and *SKF*, along with *ABS/Alfa-Laval*, are the most conspicuous of the Swedish "genius" industries; the origins of both are to be found in two separate inventions made at roughly the same time - the Dalén lighthouse system and the Wingqvist self-regulating ball-bearing.[68]

AGA - Svenska AB Gasaccumulator - grew out of the Gothenburg firm of *Svenska Carbid & Acetylen AB,* founded in 1889.

Acetylene lighting was the latest fashion on the continent at the turn of the century, and in 1901 the Swedish carbide firm acquired the patent rights for Scandinavia of the French invention "acétylène dissous". In that same year the firm moved to Stockholm, where its representative had been the engineering firm of *Dalén & Celsing*, run by two Chalmers engineers of those names. The former of them, Gustaf Dalén, was appointed chief engineer and works manager at *Svenska Carbid* in 1901. Three years later, when the future of the acetylene lighting business was looking gloomy following a number of accidental explosions, he left the company, but later on during 1904 Dalén accepted an offer to become consulting engineer to *AB Gasaccumulator,* as the company was now named. He became the company's chief engineer in 1906, and when it was reorganized and given its present name in 1909, Gustaf Dalén was appointed managing director of *AGA*, retaining the post until his death in 1937.

Dalén's destiny was originally supposed to be the care of his parents' farm, and he did indeed take a great interest in agriculture. He was interested in technical matters from an early age and around 1890 designed an apparatus for testing the fat content of milk. This invention became of great importance for his future, for it brought him into contact with Sweden's leading technicians of the day and also motivated him towards the technical education by which he became a highly qualified engineer. This happened when he went to Stockholm in 1892 to show his invention to Gustaf de Laval. Since de Laval had recently designed a similar apparatus himself, he was very surprised and became interested in Dalén. De Laval advised him to acquire a thorough technical education and offered him a job at the de Laval laboratory.[69]

Dalén commenced his studies at Chalmers in 1892 and graduated from there with high marks in 1896. Next he studied at the technical university in Zurich for a year. Back in Sweden again, he spent the period 1897-1901 working on the design for a hot-air turbine in collaboration with another Chalmers engineer (A. Hultqvist). The De Laval Steam Turbine Company followed the progress of the two engineers' design work with interest and in 1899 offered them the chance of conducting experimental work at the de Laval plant in Stockholm. However, this experimental work on the turbine came to an end as far as Dalén was concerned in 1901, when he founded the above-mentioned engineering firm.

Dalén was a very creative technician. He realized early on the potentialities of acetylene, along with oxygen, for welding and cutting work: when he gave a demonstration of welding in 1902, it was considered "interesting, but without practical importance"[70]. During the years 1904-06 he made several inventions that led to the AGA lighthouse - the flasher, the sun valve and the AGA-mass.

However, his activities brought financial problems in their train which were not solved until in 1909, when the company was reorganized with the financial backing of non-Stockholm interests. Glete has drawn attention to the astonishing fact that the leading financial institutions in Stockholm at this time were not interested in the reorganization of the company, raising the question whether this may have had something to do with the negative aura generated by the lack of financial success attending many of de Laval's designs.[71] But the situation changed in 1912. The breakthrough into the international market came with the AGA lighthouses for the Panama canal - in the same year as Gustaf Dalén was awarded the Nobel prize for physics.

The AGA concern had four cornerstones - the flasher, the AGA-mass, the sun valve and the Dalén-mixer - and other products have been logically developed from these. Looking back at events from the standpoint of the middle 1950s, the only one not directly linked with the original four was Dalén's last invention, the AGA-stove.

No explicit description of the AGA research organization exists, and this is quite natural since industrial laboratory work figured significantly in production from the outset. When Dalén and his partner started up the *Dalén & Celsing* engineering firm at the turn of the century, Dalén also had a laboratory at home for his experiments.[72]

The second cornerstone of the AGA concern, the AGA-mass which solved the problem of storing "dissous gas" under high pressure, was the result of some crucial experimentation. Dalén started experimenting in collaboration with H. Sköldberg, a qualified chemical engineer, and by the summer of 1906 the AGA-mass was ready for production.[73] The stories of the other cornerstones are similar, as are those of other products in the AGA range.

An exhibition of AGA's products in 1954, fifty years after the foundation of the firm, showed clearly how crucial technological developments had led from one product to another.[74] It was emphasized that AGA still lived by its inventiveness, and that the electro-mechanical and welding laboratories were involved in experimental work of various kinds.[75] But no separate R & D department existed: industrial laboratory work, research, experimentation and design were organically integrated in AGA's intensive engineering production.

SKF - **The SKF Ball Bearing Company** - was founded in 1907. The firm was based on Sven Wingqvist's invention of the self-regulating or spherical ball-bearing.[76] In the course of the decade 1910-1920, *SKF* developed very rapidly into one of the largest Swedish companies and became a world leader in its particular industrial branch of manufacturing industry.

The history of *SKF* up to the 1920s was very closely linked to its founder, and Wingqvist was the firm's managing director during these years. However, health reasons forced him to relinquish his post in 1918.[77]

Wingqvist graduated in mechanical engineering from Örebro technical college in 1894 (the college having been founded in 1857, as we have previously noted). In the following year he studied textile manufacturing, and after that he acquired practical training from engineering firms in Sweden and the United States. In 1896 he secured an appointment with the well-known Swedish textile firm *Jonsereds Fabriker*, then in 1899 became production engineer at another widely-known textile firm in Gothenburg, *Gamlestadens Fabrikers AB*, which was owned by the families of Carlander and Mark . He made several study-tours abroad on behalf of this firm with a view to improving its production technique. Up to this time, it is said, he was merely one competent engineer among many, but he was destined soon to stand out from the crowd. He showed great technical talent, with an exceptionally strong streak of technical ambition manifested for example in the way he devoured international technical journals and other professional literature.[78] Naturally he also acquired useful knowledge from older engineers and managers.

Wingqvist was particularly interested in the problems of bearings, which were of long standing; he realized that the existing ball-bearings could be improved. In a speech on the subject in 1907 to the Technical Society (*Tekniska Samfundet*) of Gothenburg, a society of high prestige supported by Chalmers, Sven Wingqvist drew attention to the importance of the work of R. Stribeck, a German professor in metallurgy who had published certain scientific findings relating to both the theoretical and the practical aspects of these problems in 1901.[79]

By this time Wingqvist had managed to interest the owners of the textile firm in his experiments with ball-bearings and convince them of the potential importance of these bearings. He secured the financial backing that he needed, with the result that *SKF*, based upon his invention, had been founded earlier in the same year as the aforementioned speech was made.

The company's growth was very impressive, and six years later, when its shares were issued in 1913, their value on the Swedish stock exchange was one of the highest recorded. In fourth position, it was behind Ericsson but ahead of Separator, but whereas the successful development of the telephone and separator companies had been the work of a generation, SKF's history went back only six years and the company's most crucial expansion had occurred after 1910.[80]

Wingqvist's studies of the ball-bearing were complicated at first by his lack both of a laboratory and of assistants; he is said to have had "just his brain and his drawing-board."[81] But things improved: indeed, they had to be improved, for during SKF's early years Wingqvist was in effect managing director, works manager, administration manager and salesman rolled into one![82]

On the production side, Wingqvist was especially interested in rationalization and the improvement of product quality. The qualified engineers backed him in these aims, and in accordance with his philosophy of industrial production, experimental work, whether in the field of engineering design or metallurgical analysis, was a fundamental activity.[83]

The company having encountered problems with regard to the quality of the steel it used as raw material, it was decided towards the end of 1911 to establish a laboratory for research into both the material used and the ball-bearings produced. This event has been described as a milestone in the history of SKF[84], and when the facilities were tripled in 1916 it became a very advanced laboratory.[85] U. Forsberg, a mining engineer, was appointed laboratory head. He was a graduate of *KTH* and had been employed at the *KTH* Materials Testing Laboratory in 1906. To improve his metallurgical skills Forsberg had made study-tours to Germany and England; while in the latter country he had spent a term at Sheffield University. He was succeeded at SKF in 1915 by A. Hultgren, another engineer highly skilled in metallurgy. The latter too had graduated in mining engineering at *KTH* and had also studied at the Technical University of Berlin.[86] On Hultgren's being appointed chief engineer in SKF's metallurgical department in 1918 he was succeeded as head of the laboratory by Dr A. Westgren, another talented metallurgical researcher and a student of The Svedberg[87], the renowned Swedish professor of physical chemistry at Uppsala University.

The laboratory's range of activities was very wide. It will suffice here to take note of the laboratory's very great impact on the development of the metallurgical and mechanical characteristics of steel, on new testing methods and on new inventions, all of which enabled improvements to be made to the working life and load-bearing capacities of ball-bearings.[88]

Efficient, high-quality production was the watchword, as we have already said. To this end, piecework was introduced on a considerable scale, and a special control section had been established at SKF from its inception to check the quality of production.[89] But there was no detailed planning of the production process until towards the end of the First World War, when Forsberg returned to Gothenburg in 1918 after three years in the United States; SKF is said to have been one of the first industries in Sweden to put into practice the principles associated with Frederick Taylor and so-called "Taylorism".[90]

As regards the concept of backward and forward vertical integration, however, SKF was well aware of its potentialities from the outset: from both a technical and a commercial point of view Wingqvist wanted a system without middlemen[91]. To ensure supplies of high-quality steel as raw materials, SKF purchased one of the leading Swedish manufacturers of quality steel, the aforementioned Hofors Ironworks (*Hofors Bruk*), in 1916. It was in conjunction with this purchase that expansion of the laboratory was effected[92] - a laboratory which, it may be observed, accords very well with the broad description of an industrial research laboratory presented in this section.

As regards forward integration, Wingqvist endeavoured from the outset to build up a sales organization based on the principle of direct sales. In this he succeeded, probably very much under the inspiration of the German *AEG* company, which had established an enormous international organization under the direction of Emil and Walther Rathenau. Wingqvist was kept well-informed about this organization by a friend of his in the employ of AEG's Swedish affiliate, but he was also inspired by Swedish companies such as *AB Sandvik* (see below) and *AB Separator*. Both these companies had established a modern direct sales organization similar to the one that SKF set up.[93]

In the course of a decade from its foundation, SKF had spawned an entire industrial concern, with mines, steelworks, manufacturing plants and subsidiary companies under its ownership and a sales organization in place on all the major international markets. The foundations of successful future development from the 1920s onwards had been laid.

It needs to be underlined once more that the foundation and development of SKF was the result of Swedish technical and organizational proficiency which certainly received inspiration from abroad but which also had a domestic origin. As has been shown in our account of the foregoing quartet of selected

Swedish "genius" industries, Sweden conforms to a general pattern of industrialized nations in which technical education and competence, combined with various forms of industrial research, were essential. Network relations between the technical institutions and industry in Sweden, similar to those existing on the continent and in the United States, explain a large proportion (though how large is impossible to say) of the successful development of the "genius" industries.

The "older" industries

But what can be said of the older Swedish industries with their roots in the mid-19th century era? Were they completely untouched by similar but older network relationships, and were formal technical competence and industrial research totally unknown to these firms before the 20th century? Furthermore, did they, in the early 20th century (i.e. prior to the First World War), disregard these requirements or the need for industrial research? These vital questions must be answered if Swedish industry in the early 20th century is to be properly understood.

Our four selected industries in this category provide examples of fairly successful large Swedish companies: one of them, *AB Sandvik*, remains one of the leading Swedish firms to this day. Another of them, *Kockums*, still holds a leading international position in marine technology, while the other two firms, *Bolinders* and *Köpings Mekaniska Verkstad*, have formed part of the *Volvo* concern for many decades. In a sense *Sandvik*, being based on a specific invention, merits a place among the Swedish "genius" industries presented above, but the other three are ordinary engineering industries whose product-range during the 19th century was broad or unspecialised.[94]

In all these companies we find from the outset both technical proficiency in management and an awareness of the importance of advanced technical education. Frank Henrik Kockum, founder of **Kockums** (Malmö) in 1840, had very close contacts with *Motala Verkstad*[95] and was very influential in the establishing, in 1853, of the Malmö technical college mentioned earlier. Professor Palmstedt of Chalmers, an important figure in the history of Swedish technical education[96], likewise played a significant role in the process. The prestige attaching to technical education is illustrated by the education and careers of the sons of F.H. Kockum. They both studied at the Malmö technical college and later on at technical universities in Germany. When *Kockums* went into shipbuilding in 1870, the elder son became manager of that branch of activity, while the other son succeeded his father as manager of the Kockum engineering business in 1875. From the 1880s onwards, the firm's technical management was strengthened by employing highly qualified engineers, for example with degrees from Chalmers but also with practical experience from Germany. The third generation of Kockums personified the trend: studies at a European technical university were followed by further studies in the United States before returning to take up management posts in the firm. *Kockums* grew to the status of a large-scale industry; production was modernized; and in the early part of the decade 1910-1920, serial production of standardized ships was started.

Like *Kockums*, the Stockholm firm of **Bolinders** employed qualified engineers with extensive knowledge of the engineering industry, both national and international. As I have pointed out elsewhere, when the two founding brothers established their firm in 1845 they possessed an intimate knowledge of the technological and industrial frontiers of both the iron and steel and the engineering industries.[97] The network between *Bolinders*, the technical institutions and the Royal Swedish Academy of Sciences, for example, was close. From the 1880s onwards the firm was in the hands of a new generation of Bolinders with qualifications from Swedish and European technical universities and practical training in Britain and the United States, assisted by the qualified engineers on their staff. The firm secured the benefits of German (*Borsig* of Berlin), Belgian and French expertise by employing engineers with the relevant experience. Alongside the introduction of new products such as the oil engine, an "americanization" of the product-range was set in motion around 1900. Whereas previously the latter had been orientated largely towards "individual" products, there was now an increased emphasis on precision of production, long production runs with continuous work, and more automatic machines.[98]

The founder of **Köpings Mekaniska Verkstad** in 1856 was Otto G. Hallström, a civil engineer and one of the first group of engineers to graduate from what was to become Stockholm's technical university: he ran the firm for almost a quarter of a century. That its products were of high quality may be illustrated by the fact that the prototype of the Gustaf de Laval separator in 1881 was constructed by the Köping engineering firm. It is also fairly evident that the firm kept its fingers on the pulse of international technical developments. In 1883, for example, the younger son of the firm's founder brought new ideas into the company after having spent four years in the United States. These ideas revolved around more rational production of articles similar to those manufactured at Köping and standard series for the dimensions of holes and drills. It may also be observed that *Köpings Mekaniska Verkstad* was the second Swedish industrial firm to become electrified, the operation being carried out by *ASEA* in 1892 under the direction of A. Lindström, the engineer mentioned above who became a professor at KTH later on.[99]

The last of these firms is **AB Sandvik**, founded in 1862. A new epoch in the history of the iron and steel industry opened about 1860 as a result of the Bessemer method. The pioneer of the method in Sweden was *AB Sandvik*. It is true that Henry Bessemer devised it in the middle 1850s, but its practical application did not come until a few years later. It was development work by G.F. Göransson, a Swede, which made this possible. The international exhibition in London in 1862 marked the definitive appearance of the Bessemer method on the international scene, not to mention the establishment of one of the best-known Swedish firms in the iron and steel trade.

It seems very obvious today that the technological competence of G.F. Göransson, nurtured by his personal contacts and other types of network relations, was of a high order by the time he brought the Bessemer process to fruition. Although lacking in formal qualifications, Göransson was familiar with the technological frontiers of metallurgy in the 1850s. This made possible his further development work on the Bessemer process in the early 1860s - an achievement not officially credited to him until the turn of the century![100]

Although *AB Sandvik* had financial problems during certain periods of the 19th century - for example, the firm underwent reconstruction in 1868 - it was renowned from the outset for the high quality of its steel and related products.[101] We find two engineers and one laboratory assistant employed by the reconstructed firm towards the end of the 1860s. By the middle 1880s the number of engineers had increased to four and by 1895 to five; to these should be added one laboratory assistant. Ten years later, i.e. by the middle of the first decade of the 20th century, the number of engineers employed by Sandvik was about ten, a figure which had more than doubled by 1917.[102] It was A.H. Göransson (son of G.F. Göransson)[103] who during his period as manager of the firm between 1900 and 1910 built up an excellent new-style direct-selling organization - a form of marketing in which *Sandvik* was one of the Swedish pioneers. After his death in 1910, Göransson was succeeded by a qualified engineer who remained managing director of the company until 1920.[104]

It seems fair to conclude that during the second half of the 19th century, in Sweden as on the continent, qualified engineers had become an indispensable factor of industrial production and that by the turn of the century they were extensively employed in major industrial firms of every type, i.e. not only in the "genius" ones but also to a considerable degree in those larger-scale firms that were established around the middle of the 19th century. It is very important to stress the point that even at that comparatively early date we find a certain proportion of engineers in management or other senior positions in engineering firms. But their relative importance increased during the century of course, and this fact was realized among "older" firms.[105] It needs to be emphasized, however, that the Swedish engineering industry was in no way characterized by backwardness in these respects.[106]

This established fact leads on to the second question posed with respect to laboratories and industrial research. To what extent did they exist and how much "industrial research" was practised?

A simplistic answer to such a question would be that it was practised to only a very limited extent during the 19th century, especially in the manufacturing firms we have studied (*Kockums, Bolinders* and *Köpings Mekaniska Verkstad*), and in the *Sandvik* iron and steel firm as well. To say this, however, would be to ignore the historical dimension of industrial production on the one hand while focusing attention on the institutional aspect of production on the other.

Drawing departments, model-building and model collections must be characterized as early or primitive forms of industrial research: such sections were established at Kockums, Bolinders and at the Köping firm (although late on in the latter case). Kockums had a separate office for machine drawings from 1861 onwards, and when ship-designing began, a separate drawing office for such drawings was established too. Similarily, Bolinders had model workshops and model crafts (1862), but also a "*laboratory* for such processes as tinning and enamelling, the finishing and embellishing of copper- and other metalwork", and so on.[107] But of course, as Gårdlund has emphasized: "/.../ the work tasks of the technical office were limited by virtue of the primitive techniques of former times:/ .../".[108] In the case of Köpings, improvement of production technique was the dominant issue, and the introduction of micrometers and caliper gauges in the mid-1880s, for example, must be viewed in that perspective, as also must the introduction of detail drawings in 1889. However, specific research *departments* were never established in these firms: applied science in the form of mechanical engineering was the thing!

At *AB Sandvik* a slightly different pattern is observable because of the difference in the type of products. We discussed above the importance of G.F. Göransson in developing the Bessemer process, but we now turn our attention to the development of the firm after its reconstruction in 1868. It was in the latter year, moreover, that a special design department was established at the ironworks.[109] The performance of the latter particular unit in terms of both quantity and quality then improved as time went on.

The earliest researches in chemistry at *Sandviken* had been limited to the experiments conducted by professor Eggertz,[110] but in 1865 a laboratory was established specifically for the purpose - "a chemical institution for steel testing" - and a qualified chemist was employed as its head.[111] Subsequent institutional developments in the research field at *AB Sandvik* include the establishment, in 1868, of a special department of metallurgy, with its own under-managers including one for open-hearth work (1898/1900), for example. Other special departments were opened in 1868 ("Hot-rolling mill and Forge") and 1876 ("Wire-drawing shop").[112]

Around 1910, a laboratory was established in which research was conducted in chemistry. This laboratory came under the metallurgical department in 1916, when a separate organisation with separate under-managers, for research in chemistry and physics respectively, was introduced. However, no specialized research laboratory existed at Sandvik until 1934! Here again, as we have shown in our discussion of the Swedish "genius" industries, the institutional developments came later than was the case in the United States, for example. But this does not mean that Sweden was backward in terms of quality or in an international perspective. Design, production and "research" were all handled in terms of the national model. Special institutional entities as in the United States were rare, but Swedish industry was involved in industrial research activities at quite an early stage.

IV Concluding Remarks

Literature on the research and proficiency aspects of Swedish industrial development has tended to concentrate on the *institutional* manifestations. It has been said, for example, that it was only during the decades after the turn of the century that techno-scientific research for industrial purposes was introduced under more systematic forms: "The period around the end of the First World War saw the organization of technological research in Sweden"[113], and among several reasons for this introduction and development, the most important consisted of the demands made by war. Thus, the Royal Swedish Academy of Engineering Sciences (*Ingenjörsvetenskapsakademien*), the Wood Pulp Research Association (*Pappersmassekontoret*) and the Swedish Institute for Metals Research (*Metallografiska institutet*) were established between the years 1917 and 1920. The founding of these important institutions at this time is a fact - of an importance equal to that of the other fact to which attention has been drawn, viz. that research of great significance for industry was being conducted within the Swedish university system at that time, just as it had at earlier times. The great expansion of professorial chairs between 1870 and 1914 was of immense importance, but so also were the new research institutions related to the old-established societies and academies such as the Royal Swedish Academy of Sciences (*Vetenskapsakademien*, 1739). We should also notice at this point the financial and technical support furnished to the mining sector by the Swedish Ironmasters' Association (*Jernkontoret*), a private institution founded in 1747. As this paper has shown, however, the establishment of special *Departments of Research and Development* came late in Swedish industrial firms - during the interwar period or after, if at all. This fact is true not only of the Swedish "genius" enterprises in our sample but also of the older ones with their roots in the middle of the 19th century.

But what are we implying when we declare that Swedish industrial research and applied science were "not well-developed" and that in Sweden at the time of the First World War "only a handful of companies organized their own research laboratories /.../"?[114] As I have pointed at in this paper, this raises questions of a semantic as well as an historical character. The quality and content of Sweden's industrial output, especially, must be considered in its historical and international context.

The evidence presented and emphasized here with respect to Swedish firms, most notably the "genius" ones but also to some extent the older ones, shows that to a very large degree these firms had qualified engineers in management posts from an early stage. Industrial "research" in its more primitive forms was also practised during the 19th century, but it is also evident that as time went on this activity developed on increasingly scientific lines. However, according to Gunnar Eriksson, technology "never totally fused with science" during the period 1870-1914.[115]

I will not argue over that point, but given the rather imprecise definition of "research" and the fact that "industrial research" covers such a broad span (see above, section III), it is important to point out the high standing enjoyed by industrial technology in Sweden towards the end of the 19th century as well as in certain sectors of Swedish industry during earlier decades.

The very complex relationship between scientific progress and its application in Sweden during the period of its industrial revolution has also been discussed by Eriksson, who lays much stress, for example, on the functions and workings of the materials testing institutes associated with KTH and Chalmers (founded in 1896[116] and 1888 respectively), and on the consulting engineers and the civil service departments such as the Telegraph and Telecommunications Board, as well as on the fact that in private industry, laboratories and departments for testing raw materials and finished products were installed not only for routine controls but for research purposes too. Eriksson likewise remarks on how some of the Swedish inventors of greatest importance for the metal and machine industry "came very close to doing research of a scientific or at least technological kind."[117] Two persons of significance in our discussion as well - Gustaf de Laval and Gustaf Dalén - are singled out as examples along with Alfred Nobel, the founder of the Nobel prize.

Given this very complex situation with regard to industrial research and technical proficiency, it is pertinent to draw attention to the fairly advanced Swedish position in these respects. An awareness of the need for advanced technical competence in industries which were predominantly large-scale had existed, at least at management level, since the middle of the 19th century, and this awareness intensified as time went on. As industrial research guided or managed by scientifically-trained engineers became increasingly vital, so the importance of such engineers was realized. This paper has also shown that a large proportion of qualified engineers were active in private industry, a fact indicative of the technical and industrial proficiency of industry.[118]

This having been said, it is also evident that in Swedish industry and society, as elsewhere in the industrialized world at the time, varying opinions prevailed as to how best an engineer should be educated, as well as different schools of thought concerning the engineering profession as such. Of two distinct "schools" in this regard, an older form had its roots in the Swedish tradition of civic service, which emphasized the scientific skill of the engineer and his impartiality in society. In the early 20th century this ideal, to quote Sundin, "was set against that of the 'modern' engineer."[119] The latter view stressed the role of the engineer as manager in industry, "placing importance upon his ability to manage a modern business enterprise both with regards to economics and administration." The founding of the Academy of Engineering Sciences in 1919 was the institutionalized sign of the synthesis of the two "schools".[120]

But what it is important to underline yet again is that with respect to industrial research and technical proficiency, Sweden fits into an international pattern - but a pattern which had its national features. For example, it has been said that Swedish industrialists "later on" were both inspired and intimidated by the spectacular technical progress shown by Germans and Americans at the turn of the century, and that "The role of science and technology in the industrial expansion was noticed and compared to the modest Swedish situation."[121] While this paper has shown that in various ways Swedish industry was in close touch with German and American developments as well as British and French, it has also demonstrated that such a proposition as the one above underestimates the Swedish situation prevailing both then and during earlier decades of the 19th century.[122] As regards technical proficiency in laboratory work and industrial research, in certain industrial sectors Sweden was operating on the technological and industrial frontiers of the day. Important explanatory factors in this regard are the established contacts and networks which existed, and had done for a long time, between Swedish and foreign industry and the Swedish and international technical schools, public and private institutions and organisations, and so forth.

In Sweden as elsewhere in the industrialized world, the interwar period brought an array of novelties and innovations expressed in such terms as "Taylorism", "scientific management", "rationalization movement" and the like; one of these is the concept of the 'modern' engineer. It has been convincingly argued, however, that the concept of rationalization is very vague, and also that prior to the First World War it referred mostly to mechanization.[123] Robert Locke's assertion that "the state of scientific knowledge" around 1900 "was of little direct use to managers" supports this view - although he also declares that the "education-management connection" should not be exaggerated as far as the 19th century is concerned![124]

During the interwar years, however, time-and-motion studies, internal statistics, bookkeeping, cost-analysis and similar practices drawn from business economics were introduced in order to restructure and so rationalize the enterprise. The examples set in these respects by Germany and America had a very great impact on developments in Sweden. But when we observe that many of the large Swedish industrial firms had no specific *departments* for R & D prior to the interwar period, and in some cases not until after the Second World War, if at all, this does not indicate any backwardness of technological and industrial development in terms of the quality of the industrial products being manufactured. Our selected Swedish industrial firms show that, from a technological and industrial point of view, in the early 20th century they were very well acquainted with, and to a large extent operating on, the industrial frontier of the day.

In the introductory chapter of his book **Science and Technology in History. An Approach to Industrial Development** Ian Inkster writes: "Economic development in nineteenth-century Europe illustrates that success may result when there is a coalescence of appropriate technologies, transfer mechanisms and institutional adaptions."[125] The case of Sweden may be considered a good example in these respects. The results achieved by a number of Swedish industrial firms in the early 20th century have been presented and discussed in this paper. In the case of the so-called Swedish "genius" industries or firms especially, developments have continued on successful lines.

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NOTES

1 The growth of industrial production (value added at fixed prices) 1868-1912 was 4.9 % per annum; see Schön (1988), Table I14.
2 See Schön (1982).
3 See Ahlström (1991).
4 The presentation is somewhat lengthy but important to the argument.
5 See Schön (1982), p 15.
6 See Jörberg (1961), (1973) and Schön (1982).
7 The importance of large-scale industry was even more pronounced in terms of total value of production; see Jörberg (1961), Table at p 134.
8 Birr (1957), p 2.
9 Ibid.
10 Ibid., p 16.
11 See Freeman (1989), p 308.
12 See Schmookler (1968).
13 See Kocka (1980), p 95.
14 Birr (1957), pp 9-10.
15 See Sundin (1991), p 267.
16 Chandler (1977), pp 374-75.
17 See Birr (1957), p 31.
18 Ibid., p 88.
19 Ibid., p 17.
20 Committee of 1907, p XXVI.
21 See Ahlström (1993a), (1993b) and (1982).
22 See Torstendahl (1975), p 155.
23 The proportion in the private sector was approximately 70 %; see Holmberger (1912), Bil. VIII.
24 Committee of 1907; Table I, pp 490-91.
25 However, the average figure for the industry as a whole was 4-5 factories to every technician, and the committee's conclusion was that "technical education has not yet asserted its full right to manage our industry". Added to this was the fact that technicians worked in drawing departments, laboratories and business offices, which meant that the managerial role played by trained engineers was considered remarkably small in relation to the numbers of factories and factory-workers. Ibid., p 31.
26 See footnote 21.
27 See Dahn (1936).
28 See Glete (1987), p 248.
29 The information on *Ericsson* is based on Attman, et al (1976), Vol I and III.
30 Ericsson formally retired in 1900, but was atcive to 1903. Cedergren was manager and a member of the board until his death in 1909.
31 See *Attman*, et al (1976), Vol I, p 47.
32 Ibid., p 363, footnote.
33 Ibid., p 57.
34 Ibid., p 81.
35 Ibid., p 365, note 31. The others were line-workers, troubleshooters and adjusters.
36 Ibid., p 80.
37 Ibid., p 117.
38 Attman, et al (1976), Vol III, p 2.
39 Ibid., p 397.
40 Ibid., p 398.
41 The information here is based on Althin (1943), Gårdlund (1983), Fritz (1983) and Glete (1987).
42 See Gårdlund (1983), p 18.
43 Ibid., p 13.
44 Ibid., p 76.
45 Ibid., p 155.

46 See Althin (1943), p 129.
47 Ibid., p 137.
48 See Gårdlund (1983), pp 220-21.
49 The information here is based on the situation of 1907/08 as depicted in a book written by one of the engineers at *ABS;* see Gårdlund (1983), p 245 ff.
50 Ibid., p 249.
51 Ibid., pp 252-53.
52 Ibid.
53 The number of other staff employees was 41 in 1913; see Gårdlund (1983), p 293.
54 The sources for this section are Glete (1983), (1984), (1987) and Helén (1956).
55 See Glete (1983), p 28.
56 Ibid., p 36. Jonas Wenström died in 1893.
57 See Helén (1956), Vol I, p 53.
58 Ibid., p 96.
59 The place of the Zurich *Eidgenössische Technische Hochschule* in the history of higher technical education is discussed in Ahlström (1982), chapter 2.
60 See Glete (1983), p 29.
61 Ibid., p 30.
62 Ibid., p 41.
63 Ibid., p 48.
64 After Helén (1956), Vol I, p 211.
65 See Helén (1956), Vol I, p 214.
66 See Glete (1983), p 70.
67 See Helén (1956), Vol I, p 217.
68 Our main sources in this section are AGA (1954), Steckzén (1957) and Glete (1987).
69 AGA (1954), p 11.
70 Gustaf Dalén (1969), p 6.
71 See Glete (1987), p 258.
72 See AGA (1954), p 13.
73 Ibid., p 25.
74 See AGA (1954), p 37.
75 Ibid., p 36 f.
76 The sources here are Steckzén (1957) and Glete (1987).
77 He returned as chairman of the SKF board in 1938.
78 See Steckzén (1957), pp 34-35.
79 Ibid., pp 33 and 39.
80 Ibid., p 155.
81 Ibid., p 43. For an account of the development of Wingqvist's design work from a technical standpoint, see Steckzén (1957), p 61 ff.
82 Ibid., p 91.
83 Ibid., p 129.
84 Ibid.
85 See Sundin (1981), p 181.
86 The importance of the Berlin *Technische Hochschule* in the history of higher technical education has been discussed and emphasized; see Ahlström (1982), chapter 2.
87 See Sundin (1981), p 182.
88 See Steckzén (1957), pp 131-32.
89 Ibid., p 103.
90 Ibid., pp 293-94.
91 Ibid., p 83.
92 Ibid., pp 204-10.
93 Ibid., pp 87-88.
94 The main sources of information on these firms are Kockums Mekaniska Verkstads AB. Malmö 1840-1940 (1940), Gårdlund (1945), Fransson (1982), Hedin (1938) and Glete (1987).

[95] *Motala Verkstad* was the leading Swedish engineering firm around the middle of the century. It was founded in 1822 for the purpose of constructing lock-gates and iron bridges for the Gota Canal.

[96] See, for example, Ahlström (1982), p 40.

[97] See Ahlström (1991), pp 40-41.

[98] In 1932 the firm merged with *Munktells Mekaniska Verkstads AB* of Eskilstuna, an engineering firm founded in 1832, to become *AB Bolinder-Munktell*. All production was moved to Eskilstuna. The firm became a **Volvo** subsidiary company in 1950.

[99] A number of advanced products were manufactured by the Köping firm. Examples of these were the side-planing machine in the 1890s and, coming into production at the turn of the century, the so-called high-speed steel used in the manufacture of tool steel. Transmission gears for cars formed a further example during the 20th century. This product was launched in 1926 - and a contract was signed with **Volvo**.

[100] See Ahlström (1991), pp 38-39.

[101] Examples are strip steel, fully-rolled tube products, cold-drawn wire, carbide tools and rock drills.

[102] See Hedin (1938), p 382.

[103] G.F. Göransson, the founder of *Sandvik*, had died in 1900.

[104] T. Magnusson, brother in law of A.H. Göransson and on the staff of the firm for many years. Magnusson was succeeded as managing director by A.H. Göransson's brother. The latter had studied in Lausanne and at Columbia University in New York; he had also had practical experience at ironworks in Germany and England.

[105] Around 1880 it is also very evident that owners and managers in Swedish large-scale industry were "educated men" and "upper-class." See Carlson (1986) and Jörberg (1988).

[106] See also Glete (1987), p 247.

[107] Gårdlund (1945), p 57. Originally in italics.

[108] Ibid., p 63.

[109] See Hedin (1938), p 183.

[110] Ibid., p 185.

[111] A chemical engineer named Collberg.

[112] Hedin (1938), pp 185, 380.

[113] Sundin (1981), p 207.

[114] Ibid., pp 207-8.

[115] Eriksson (1978), p 207.

[116] The forerunner of the KTH testing institute or laboratory was an institute founded in 1875 by the Swedish Ironmasters' Association.

[117] Eriksson (1978), p 206.

[118] The development is reflected in the heavy increase of white-collar workers in the Swedish industrial sector. Between 1896 and 1910 the annual increase of this category was 6.6 per cent, while the corresponding figure for blue-collar workers was only 3.3 per cent. Furthermore, the increase of white-collar workers was especially accentuated in innovative growth-branches. See Schön (1990), p 21 ff. In this study, Schön analyses the importance of electricity in the development of Swedish industry from the 1880s to the present time.

[119] Sundin (1981), p 210.

[120] Ibid., p 211.

[121] See Berner (1981), p 110.

[122] Among other things the Swedish results at international industrial exhibitions support such a view; see Ahlström (1991) and forthcoming study.

[123] See DeGeer (1978), p 360.

[124] See Locke (1993), pp 32-33.

[125] Inkster (1991), p 30.

DAN CH. CHRISTENSEN[1]

Technology Transfer or Cultural Exchange?

A History of Espionage and Royal Copenhagen Porcelain

The ordinary model of technology transfer guiding historians' understanding of technological development during the agricultural and industrial revolutions may be described something like this:

The world consists of technologically advanced centres of technical inventions envied by a less developed nation states suffering from technical backwardness and incompetitivenes in world trade. According to predominant mercantilistic doctrine world trade was a zero-sum game. Hence it was a patriotic endeavour for the less advanced nation states to catch up at the expense of their more fortunate competitors by whatever means available. A national policy of technology transfer was adopted to stem the ingoing flow of foreign goods and the outgoing flow of precious metals. Espionage was an essential method to acquire foreign technical intelligence.

British textile machinery and coal-based technologies of metallurgy and chemistry were obvious targets of Continental European espionage. At its best it was organized by governmental departments, as the Bureau of Commerce, headed by the Trudaines, father and son, in France in the middle of the 18th century, and the Prussian Gewerbeamt, headed by P.C.W. von Beuth in the beginning of the 19th.[2] A well organized technology transfer would gradually develop into a comprehensive system, realizing that technology transfer is not a simple matter of moving artefacts to the recipient country, but a very complicated process involving tools, skills, adaptation and implementation. The victim, typically Great Britain, was no passive witness to the illegal activities by foreign agents, particularly since some of her own metallurgical and chemical industries owed a great deal to equally subversive methods. On the other hand, Britain was no centralized police-state, so protective countermeasures were hard to enforce.

Of course, there were exceptions from this general picture. The roots of the British agricultural revolution are generally seen as originating from the Netherlands, France and Italy and being transferred by English agriculturalists expatriated during the Cromwellian revolution. Swedish iron production aroused great curiosity when Britain ran short of char-coal for smelting British iron-ore. In the early 17th century Saxony was the leading nation in cobalt-blue and true porcelain. Do these exemptions only restrict the validity of the general model in degree, not in essence?

My own study of European porcelain technology was motivated by the assumption that porcelain differed from the ordinary model of technology transfer. What struck me was not so much that the technology was Chinese and that the time-lag between the Chinese invention and the European reinvention is believed to be about 1500 years. The outstanding feature about porcelain was the reciprocal pattern of technology transfer in Europe. What was the role of espionage in this pattern of transfer?

The other striking feature has to do with the character of porcelain, which I imagined to belong to a different category because it involved the arts. Examples of comparatively neutral technologies in terms of class and culture could be metallurgy and chemistry, mainly, perhaps, because their products are purely technological, like glass or sulphuric acid or salt or steam engines. The usage of some of these products is indirect, they are not consumed by families but by manufacturers. Or glass which was perhaps the first industrial product which did not replace a home-made equivalent, and was basically the same product whether part of Versailles or a simple cottage.

Porcelain, however, belongs to the decorative arts. It is a very complicated technology, too, which occupied the brains of scientists during the 18th century, but it does not sell without decoration, expressing not only the taste of the producer but also that of the owner. The skill to produce it was the object of rivalry between European courts, and a postrevolutionary object of rivalry between classes inside a nation state. The aesthetic aspects of porcelain as well as its class-character touched upon both European revolutions, the political as well as the industrial one.

II.

Let us begin by looking at the map of the transfer of porcelain technology transfer in Europe.[3] Apart from Meissen it is difficult to distinguish between initiatory countries and recipient countries. It rather reminds one of a Hobbesian 'bellum omnium contra omnes'.

When in 1772 Franz Heinrich Müller submitted his test-piece of porcelain to the Danish College of Commerce, he claimed to be an independent inventor of the technology of true porcelain. Müller was an apothecary by training and his scientific competence as a chemist and metallurgist was widely recognized.

Was he in fact, like Böttger, an independent inventor? Böttger's invention of true porcelain at Meissen in 1709 is no longer considered the result of an alchymist's trial-and-error-experiment; he did not re-invent the soft Chinese porcelain, but was the first in the world to produce hard porcelain based on the appropriate raw material, kaolin, a Chinese word for a certain clay, also used at the time as a wig-powder.[4]

Whereas personal transfer between porcelain factories in German-speaking countries has been evidenced, no such links have been identified with France, England and Denmark. Kaolin was sent by French missionaries in China to Vincennes, but that did not enable R.A.F. Reaumur to make a final break through. Before Macquer (re)discovered the composition and burning of true porcelain in 1771 at Sèvres, the French could only produce faience and the so-called soft porcelain. In England kaolin was found in Cornwall 1755 and W. Cookworthy soon after started a porcelain factory in Bristol, which soon moved to Plymouth. Porcelain for reasons I shall revert to never really took on in Britain.

F.H. Müller had at his disposal kaolin which had been found by Birck in 1755 on the Danish island of Bornholm, but so had Richter and Fournier, invited by the royal court from Strassbourg and Chantilly respectively, in order to invent and produce true porcelain. Whether the secrets were revealed to Müller by them, or by J.G. von Langen, royal forest commissioner and former director of Fürstenberg, Brunswick, or he got them from Macquer's chemical dictionary, translated into Danish in 1771, we do not know. Faience was or had been produced at various manufactories in Denmark-Norway since 1722.[5]

Fig. 1. F. H. Müller in his laboratory.
A Coffee-cup with a floral wreath in gold and cobalt blue border
bearing the following inscription:
The finest senses may well pleased be -
Wehn Nature leans on Science for her aid -
But art is wedlock with Utility -
Demands from skill a double debt be paid.
(translation H. V. F. Winstone *Royal Copenhagen*, London 1984)

By courtesy of Nationalmuseum, Stockholm

What we do know, however, is that his first productions, although sufficient to convince the royal court that the establishment of a porcelain Factory in Copenhagen was realistic - and highly desirable, the minster of finance and commerce, the powerful count H.C. Schimmelmann, remained skeptic. Indeed the quality of Müller's first true porcelain was not very impressive. Schimmelmann was hesitant to open the treasury. He as well as the foreign secretary, count A.P. Bernstorff, both German speaking, were well aware that porcelain factories, mushrooming in the German states, served the function of courtly vanity, but were ruinous as business enterprises. Much to the annoyance of the court and insultingly challenging the professional pride of Müller, Schimmelmann demanded certain conditions to be fulfilled, before investing public money in the shares of the procelain company. He wanted technical expertise from Meissen, Fürstenberg, Berlin, and the only way to recruit such top-trained artisans was by means of espionage. Schimmelmann, as we shall see, was not without the relevant experience. In fact he had acquired unique first-hand information.

Before dwelling on Schimmelmann's business adventures and networks, let us look at the technology Müller claimed to master. Porcelain production consists of four separate techniques.

First, the proper composition of clays and silicates. Müller's original note books prove his competence. Kaolin, quarts and feldspar was available on Bornholm, and although he had kaolin-supplies from Limoges (France) and quarts and feldspar from Norway, the factory was perfectly able to produce porcelain from domestic raw materials when the war against England 1807-14 forced it to do so. Stamping mills were necessary to comminute the raw materials. Müller used horsepower, whereas Wedgwood was the first to introduce steam-powered flint mills.

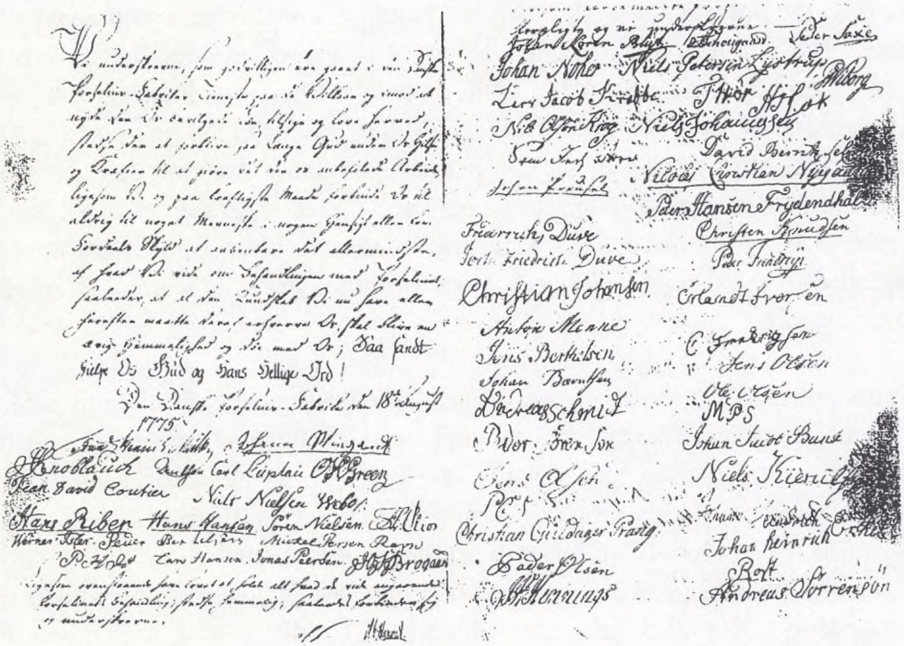
Secondly, the compound must be given its proper form, by moulding, turning or modelling. To accomplish this one needs moulds, made from gypsum, or a turning-mill, or dexterity. These caused no problems.

Thirdly, kiln technology is important. Porcelain requires a temperature of 1350-1450° C. You need fireproof bricks to close the furnace at every burning, and saggars to prevent smoke-particles polluting the porcelain. Müller built horizontal furnaces, one for each burning, which were enormously fuel-consuming. Wood was supplied in large quantities by Norway. Wedgwood fired vertical bottle-kilns with coal and invented a pyrometer to read the temperature. Vertical three-storeyed kilns, constructed at Sèvres and copied by Berlin, were introduced in Copenhagen 1804. They were saving energy, because the heat of one kiln was used for three firings.

Fourthly, the porcelain needs glazing and painting. Cobalt-blue was the favourite colour. The Chinese had imported cobalt from Persia, at Meissen in Saxony cobalt was a local monopoly, until, coincidentally, cobaltiferous ore was discovered in Norway the very same year Müller produced his first piece of true porcelain. The processing of the ore into a high quality dyestuff was a complicated and secret technology mastered only and therefore closely guarded by the Saxons. Müller's experiments with cobaltiferous slimes from Norway had succeeded to some degree, although there was still a lot to be learned to achieve supreme quality.

To sum up: By 1775 Müller's experiments carried sufficient conviction to publish an invitation to buy shares. And although only the postmaster general and the royal court proved open to conviction the Copenhagen Porcelain Manufactory was established. Müller proclaimed to be master of all stages of porcelain production. The failure of one stage would have been the failure of it all. Müller emphasized his competence as a scientist and paid almost no attention to the artistic aspect. He also presented himself as a true patriot by ending the exploitation of the trade balance whether by Chinese or European usury, as he termed it.

The royal court, or rather the former queen - the king, Christian VII being notoriously lunetic - was delighted at the prospect of presiding over a national manufactury of prestigious 'chinoiserie'. The minister of finance and commerce, count Schimmelmann, said to be one of the richest men in Europe, and particularly powerful during the formal reign of a mad king, considered the royal enthusiasm exaggerated and technically ill founded. He demanded the porcelain factory in Copenhagen as well as the Norwegian cobalt mines to be operated by professional experts, i.e. Saxons. Meissen had the porcelain expertise, Freiberg had the cobalt mining expertise. But the recruitment of these experts involved the violation of Saxon law. This, however, belonged to the routine affairs of Schimmelmann's past, to which we shall briefly turn our attention.



Saa sandt
Hielpe Os Gud og Hans Hellige Ord!

1775

Knoblauch
Carl Luplau
Jean David Coutier
Niels Nielsen
Hans Riber
Hans Hansen
Søren Nielsen
Mickel Persen
Carl Hansen
Jonas Peersen

Peder Saxe
Johan Noher
Niels Petersen
Niels Johannsen
David
Nicolai Christian Nygaard
Peder Hansen Frydendahl
Christen Knudsen
Friedrich Duve
Friedrich Duve
Christian Johansen
Anton Menne
Jens Berthelsen
Johan
Andreas Schmidt
Jens Olsen
Ole Olsen
MPS
Johan Jacob Bunse
Niels
Christian Prang
Peder Olsen
Johan heinrich Rott
Andreas Sorrenson

Fig. 2. Document signed by all employees making a vow not to disclose any secret concerning the manufactury of true procelain.

"We the undersigned who have voluntarily entered into the service of the Danish Porcelain Manufactury on conditions and against the salary offered, hereby promise to remain in that service as long as God Almighty bestows upon us the health and the power to perform the work demanded. Furthermore, we oblige ourselves never to reveal the slightest knowledge related to the manufacture of porcelain in any respect nor to our own advantage. Thus, all knowledge in our possession at the present or in the future will remain an eternal secret and die with us, so help us God and His Holy Word.
The Danish Porcelain Manufactury, 18th August, 1775."
Archives of the Royal Porcelain Manufactury, Board of Directors Papers 1774-1789, file 6-7, LAS (Landsarkivet for Sjælland)

III.

Schimmelmann started his carreer as an excise concessionaire in Dresden, Saxony, and was soon favoured by August II, elector of Saxony and king of Poland (the two forming a personal union). In his capacity as an excise collector Schimmelmann became closely acquainted with Saxon production and commerce. Therefore, when Frederik the Great occupied Saxony during the Prussian Seven Years' War, Schimmelmann was offered the service of providing the occupying army with forage, a provision to be paid, according to Prussian orders, by the occupied Saxons themselves. As part of a deal Schimmelmann consented to take over the stock of Meissen porcelain provided he could sell it wherever he wished and have incomplete sets completed at the factory. Consequently Meissen was spared by the Prussian troopers and leased by the former Saxon excise collector. The Meissen factory, of course, was the jewel of the Saxon crown, and Schimmelmann, aware of this and callous enough to serve two masters, immediately sub-leased the factory to puppets of August II. Schimmelmann earned a fortune each time, whether he was providing the Prussian king or leasing to the Saxon elector. Nevertheless, he realized that his position was getting precarious and decided to bring his stock of Meissen porcelain into safety in the neutral Hanseatic city of Hamburg; here the whole lot was sold on auction.[6]

Now outside the jurisdiction of Frederik the Great, Schimmelmann was approached a second time by this Prussian king. Would he be interested in sharing with the king the expertise of his porcelain factory by establishing a sort of joint venture in Berlin? Schimmelmann gathered that his double standard had not been disclosed, but that he was bound to be unmasked once he agreed. His pretext for declining the royal offer is interesting. His crucial point was that expert technologists, which he termed arcanists, are unrealiable because they know that the value of their labour vanishes as soon as it is no longer their private arcanum, i.e. secret. For fear of losing the value of their labour they are unwilling to cooperate. For this reason, your majesty, your project is doomed to failure, but do rest assured that it will always be my honourable duty to serve your majesty.

Count Schimmelmann could not have explained his personal strategy more clearly. Nevertheless, the conditions he was to impose in 1775 on Müller's factory as well as the Norwegian cobalt mine, were exactly what he had denounced as futile in 1760. In the meantime, however, he had invested his enormous fortune in a palace in Hamburg, an estate in Holstein and later-on another estate in Jutland, as well as another palace in Copenhagen. There he impressed the Danes by his Meissen porcelain parties and exorbitant use of saluting guns, his coach and eight, and his innumerable servants and secretaries. As Danish minister of finance and commerce he was not the civil servant of the king. He rather played the equal partner.

After the Prussian Seven Years' War the personal union between Saxony and Poland was dissolved and for the new Saxon Elector, Frederick Christian, economic recovery depended mainly on porcelain and cobalt. To protect these industries legal countermeasures were enacted to prevent foreign powers to suborn skilled artisans to leave the country. Count Schimmelmann, governing the considerable investments in competing Danish-Norwegian plants, ordered the headhunting of Saxon experts.

IV.

Let us consider the cobalt works first. Three German experts were selected to establish the Norwegian Cobalt Works. As dye-master J.W. Trautevetter was illegally enticed from Saxony. As constructor of mills, furnaces and laboratories the Saxon mining expert, G. Schram, was appointed; he was one of Schimmelmann's private employees, who had formerly been in charge of Schimmelmann's mint projects in Northern Germany as well as a coal mining project on Bornholm. The managing director of the cobalt works, C.I. Waitz, however, proved to be completely unqualified. He was no Saxon, and his experience with cobalt consisted in his uncle's incompetent management of Hasserode, a newly established cobalt factory having monopoly in Prussia. Technical failures and unwillingness to cooperate with Trautevetter and Schram were blamed on Waitz, who was dismissed immediately after the death of Schimmelmann in 1782, when authority was transferred to the Mining Bureau in Copenhagen, responsible for the Norwegian silver-, copper- and iron-mines, and mainly run by Norwegians.[7]

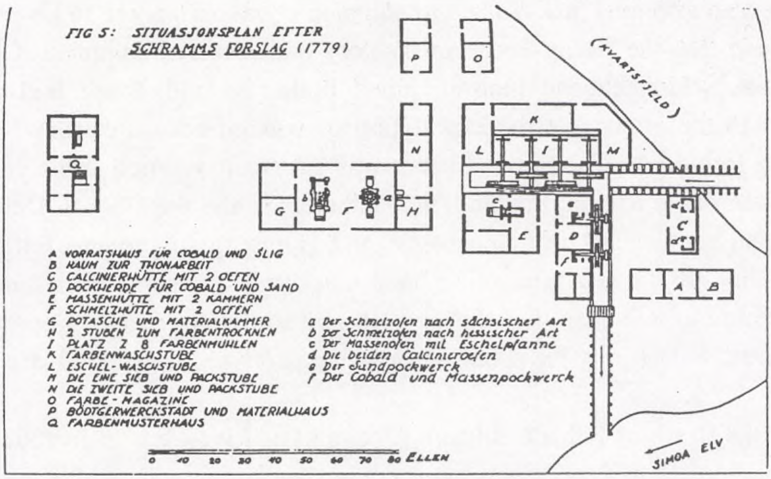


Fig. 3a. Cobalt Works Modum as designed by Schram 1779.
National Record Office, Oslo. Reproduced after Th. Lindeman, *Modums Blaafarveverk - Et Bidrag til dets historie*, i Det kgl. Norske Videnskabers Selskabs Skrifter Nr. 5, Trondheim 1932, p. 8.

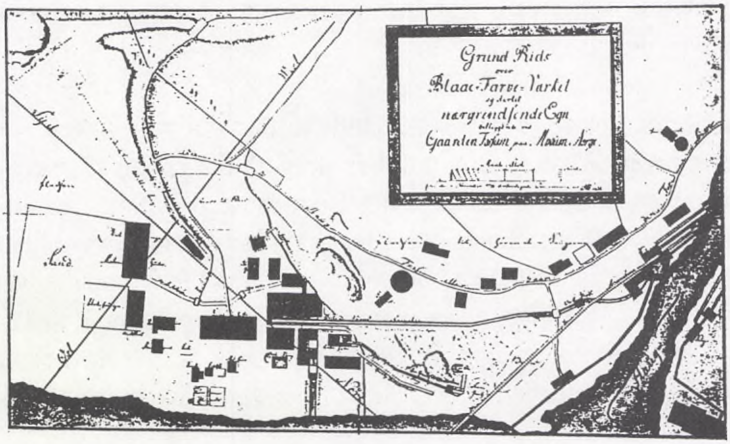


Fig. 3b. Cobalt Works Modum as modified according to intelligence collected by Ole Henckel.
Drawing by M. Kruse 1786. *OB13, National Record Office, Oslo.*
Major modifications were kilns for roasting the cobalt ore and for glass smelting, and mills for pulverizing the blue colour, as well as the construction of the arsenic tunnel.

What did the Saxon Elector know about this development? The Mining Academy in Freiberg, too, had a network of agents, and they procured cobaltiferous ore from Norway and dispatched it by coach to Dresden for further investigation. They were also informed that Waitz was shipping cobaltiferous ore to his uncle in the Harz and that the Berlin Porcelain Factory had received samples of a high quality from Schimmelmann himself, albeit both he and Waitz had signed documents to the effect that the exportation of cobaltiferous ore from Norway was strictly forbidden. The Saxon Elector was extremely worried at the prospect of losing markets in Russia, England, the Netherlands and the USA to Denmark-Norway, and sent agents to Copenhagen and Hamburg to procure further information. In 1781 he was relieved to learn that the Norwegians were unable to process the ore into dye, so that slimes were sent to the Harz or to Copenhagen for refinement. Fortunately the cobalt works were paralysed by internal strife.[8]

Following the death of Schimmelmann, a commission was set up to reorganize production. Further investments were necessary and it was decided to send a Norwegian spy to the Continent to explore German cobalt technology and to suborn skillful workers. Ole Henckel, the spy, was extremely successful. Not only did he engage a most qualified technologist, G.C. Bernstein, from Carlshaven, his report of 280 pages and drawings also contained very detailed descriptions of methods and machinery of the Harz cobalt works. Espionage against the Saxons was considered too dangerous, and the recruitment of experts from different places had proven disastrous.[9]

Henckel then decided to go to the Netherlands to find out how Dutch merchants ran the cobalt market. What exactly did they do with the cobalt to make it more valuable. Did prices of Saxon cobalt differ from those of inferior qualities? He wondered how the Dutch merchants could make the cobalt more valuable without the use of thermal energy. In the end he discovered that the windmills were used to mix different cobalt qualities, or even attenuate it with powdered sand, repack and remark it. Whatever its origin all cobalt was sold as Saxon. Disillusioned with the Dutch he recommended direct sale of Norwegian dye to the English.

Everywhere Ole Henckel aroused suspicion, although he pretended to be a private traveller interested in mining technology, and the agent of nobody. To avoid suspicion he spent weeks in local inns offering beers to the workers, who were under oath not to divulge secrets to foreigners, and who were mutually afraid of informers. When being pumped workers would try to fool him, in which

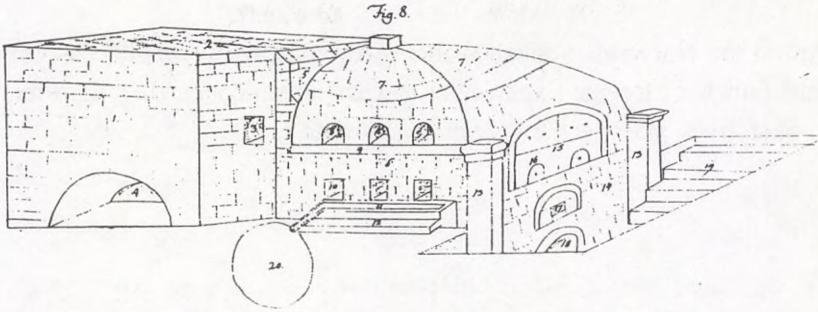


Fig. 4. Ole Henckel's sketch of the Carlshaven furnace for melting sand for glass (1-4) and for melting the glass in crucibles (5-20). The crucibles were inserted through 15 and the molten glass was tapped from 20. Ole Henckel was proud not only to have made sketches of this crucible furnace as well as machinery for processing the blue colour, but also to have recruited the master artisan of Carlshafen, G.C. Bernstein.
Om Cobold eller Blaafarveverker. Med Beskrivelse over disse Fabriker ved Carlshafen og Schwartzenfeld samt dertil henhørende Tegninger. Af Assessor Henckels Reiser og fleere Efterretninger samlede. Private Archive No. 171 (Brünnichs Samling) Fol. 110. *National Record Office, Oslo.*

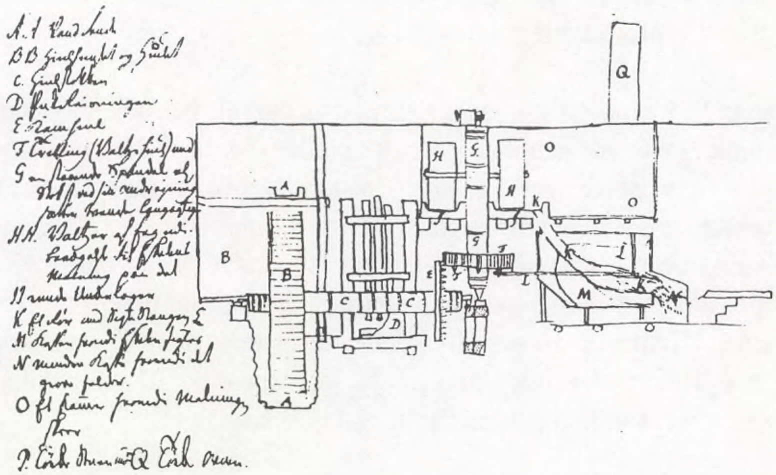


Fig. 5. Ole Henckel's sketch of a grinding mill for blue colour.
B. Water wheel. C-D mill for crushing the glass. F-H vertical grinding stones for pulverizing the glass. K tube. K. sieve. *Ibid.*

case he had to check their information by personal inspection of the machinery. If discovered spying he would assume an air of innocence.

In conclusion the Norwegian cobalt works owed its subsequent success not to a hapharzard bunch of foreign experts but to careful espionage directly aiming at the basic objectives: skill, technology and marketing.

V.

Secondly, as stated above, Schimmelmann demanded Saxon expertise for the Porcelain Factory to compensate for the suspected inadequacy of Müller. Schimmelmann and count Bernstorff, the foreign secretary ordered the secretary of the Danish legation in Dresden, August Hennings, to seduce a group of Meissen workers. At that time Marcolini, new head of Meissen, had reduced wages and Hennings, fishing in troubled waters, was able to persuade five trained workers to sign a contract with Copenhagen. The Saxon workers solemnly swore an oath to keep all secrets about Danish porcelain, just as they had formerly done at Meissen. Hennings was proud of his achievement and asked Bernstorff and Schimmelmann to comply with the promises stated in the contract, wages and naturalization papers in particular, because 'the bearer of this letter, J.G. Matthäi, who is in the secret of all aspects of porcelain manufacture, is setting off for his new fatherland hoping to find happiness for himself and his family there under your (Bernstorff's) protection'.

The campaign had exposed the Saxons to serious danger, because the victimized electorate took immediate action to prevent the illegal escape. Hennings reported that he was worried about secret attempts to stop the five artisans, 'that flattering promises and honeysweet words might shatter the simple souls.......Recently one of the five had been employed by Berlin on favourable terms, but trapped by illusive hopes he returned to Meissen, and now left a second time for exactly the same reasons.' Evidence shows that Schimmelmann's private secretariats in Hamburg and Holstein reimbursed their travel expenses. Along similar lines skilled workers were suborned from Berlin and Fürstenberg.[10]

The Meissen workers were exposed to attempts of persuasion by Saxon diplomacy even after their arrival in Copenhagen. Two of them succumbed and returned. Their fate is unknown. Those who did stay soon got disappointed. They had been enticed by promises to take up leadership of the factory. Instead they were confronted by Müller, who, having invented true porcelain all by himself, was perfectly capable of running the factory without technology transfer. He did want their assistance though, but for the training of local apprentices only. This attitude was like a declaration of war. The dispute on technological leadership and divison of labour resulted in reciprocal accusations accompanied by conspiracy and patriotic prejudice. In the end the dispute was brought before the court and the Saxons were sentenced to return to Meissen.[11] This was a repetition of Schimmelmann's mistaken strategy. Operators who know the secret processes from other factories do not readily cooperate. This had formerly happened when a government spy suborned a group of British glass workers from a single factory to set up a glass industry in Norway.[12]

VI.

Thirdly I shall relate the story of one of the most recognized Danish spies, J.M. Ljungberg, professor of mathematics and astronomy at the University of Kiel. For all we know Ljungberg started spying on his own initiative, founded on the belief that science lectures would profit immensely from practical technology. 'Mechanics, canal-building, fortification and even astronomy - apart from theory - demand experience, manual skills and practical intelligence. These qualifications are not derived from books but through travelling only'.[13] Soon he caught the attention of count Schimmelmann who used him for private as well as public ends. Schimmelmann was engaged in almost all branches of industry, sugar and cotton in the West Indies, slave-trade in Guinea, guns and textiles, pottery and agriculture in Denmark, glass in Norway, so there would hardly be any espionage report without practical value for some Schimmelmann enterprise. Ljungberg's career as a secret agent spanned the years between 1777 and 1789. All along he was collecting technical intelligence for the College of Commerce, supporting his missions.[14] In this paper I shall only refer to his last effort, his confrontation with Josiah Wedgwood, the well known British cream-ware manufacturer, during the year of the outbreak of the French Revolution.

Ljungberg was arrested in London in August 1789, at the time he was loading his harvest of three fruitful years of technical espionage in Britian on board a ship bound for Denmark. A closer look into his boxes by the customs officers revealed patented machinery, instruments, samples, models and drawings including his notebooks. While Ljungberg was in goal the customs officers gave notice to Wedgwood's partner (and nephew) in London, Mr. Byerley, who reported the interesting findings of pottery articles. So Wedgwood, assuming a stern look at a regular meeting of the Committee of Potters at Etruria Inn, announced that the following items had been seized: various pieces of cream ware, biscuit vases, plates with and without enamelled borders and prices, pitchers containing cobalt-, lead- and manganese dyes, various other minerals as well as a dozen lawns for sieving clay.[15] The fellow-potters are likely to have grumbled when their chairman further reported that the seized notebooks, although mostly unintelligible as they were in the Danish or German language, nevertheless gave evidence that Ljungberg was in possession of detailed intelligence about Staffordshire, Cornwall, Birmingham, Coalbrookdale, Derby, Manchester, Leeds, Matlock and Nottingham. It seemed likely that his collection had been made with no other view in mind than to establish similar manufactories abroad.

'It appeared to the committee, from the recollection of several persons present, that Mr. Ljungberg was in this country last winter, and contrived about the pottery, under various pretences, for some weeks, until having been detected in bribing the workmen to procure him measurements of the kilns etc., he went off suddenly, for fear of being taken up and examined, as was intended'. The committee agreed that Ljungberg was a competent and dangerous spy and that appropriate countermeasures ought to be taken to limit the damage. First of all the notebooks needed translation and this required money and a permit from the Lords of the Treasury. Once the evidence was intelligible Ljungberg should be prosecuted for violation of the tools act. Secondly this case was a useful instrument to organize employers nationwide to put pressure on the government to protect their interests. A special Ljungberg-committee was set up including famous potters as Wedgwood, Spode, Neale, as well as Matthew Boulton.

January 1790 the Ljungberg case was again on the agenda at Etruria Inn. Some manufacturers had supported the strategy of taking a firm stand, others had played the case down, because they were not victimized themselves or because they considered the seized articles to be tourist souvenirs only. The Ljungberg committee was frustrated to learn how difficult it was to rally British employers to enforce the tools act. Britain being without a police force, the enforcement of the law was the reciprocal duty of the injured employers. Secondly Wedgwood gained support to inform the fickle-minded manufacturers that it was absurd 'to dwell on the improbability of a young man without fortune, as we know he was, spending 14 years in an expensive way of living merely for his amusement,

[when] we have the best authority for asserting that he acted as an agent to a foreign state.'

At this stage the minutes state that Ljungberg had made his escape, and the efforts of the Committee of Potters petered out. Ljungberg's arrest had been hot news in the press.[16] The prohibition of export of tools and machinery had been enjoined. The prisoner, on the other hand, had been released on a bail of £ 300, paid by the Danish legation in London. Did the British government really consider Ljungberg worth less than £ 300? Or did they make a deal with the Danish diplomacy? We do not know. What we do know is that upon his return to Denmark Ljungberg contacted the foreign secretary, A.P. Bernstorff, about the seized articles. The London Embassy was immediately instructed to get hold of Lungberg's 'luggage', being of the utmost importance to him, since he had undertaken the journey to improve his technical knowledge.[17] The Danish consul, George Wolff, bought the goods on public auction, possibly via his agents, and dispatched them to Ljungberg in Copenhagen. Books and patented inventions finally reached the people they were intended for, J.L. Reventlow and Ernst Schimmelmann, both prominent members of the Danish government.[18] In January 1790 Ljungberg had resumed work in the College of Commerce. He poured out his troubles to the king saying that part of his technical drawings and models had been lost in London and humbly asked for royal indemnification.[19]

There is no evidence in the archives that the Royal Porcelain Factory took direct advantage of Ljungberg's cream-ware espionage. But that was not to expected either. The files of Danish-Norwegian faience factories from the period are lost, but it is obvious that Wedgwood technologies were transferred to them, particularly the Kastrup Factory, which had been defying keen competition by Staffordshire from the 1780s, even if the cream-ware was smuggled into Copenhagen. Kastrup had introduced coal-furnace technology and part of its production was copied after patterns from Etruria and Leeds.[20] Even the Royal Porcelain Factory which produced for prestige rather than for profit was imitating Wedgwood models.

To sum up: Espionage was a generally accepted method of acquiring technological intelligence. As far as Denmark-Norway is concerned, the initiative was rarely with the government itself, but once a spy had been recognized as useful he was supported by funding and by the diplomacy if in trouble. But we have to be careful about this, because spies, if any, who were not recognized, may have left no archival material. The victim countries, here Saxony and Britain, proved unable to prevent these illegal activities. But intelligence was not enough. Technology had to be implemented, typically by suborned artisans. The mixing of these foreign experts proved to be disastrous. In Denmark-Norway, unlike France and, later, Prussia, the dirigiste impetus was weak, mainly because leadership in the state apparatus was unstable.

VII.

This brings us on to the last theme of this article, viz. the relationship between art and technology, which was revolutionized during this period. There are striking similarities between Müller's and Wedgwood's views on this relationship. They agreed that the production of porcelain or faience or cream-ware was more than an art. It was a scientific technology. Not only the production was a question of technological division of labour, even the design itself was technological reproduction. Art historians have devoted most of their time to identify the artists behind the marks in the bottom of figures, cups and plates. But this is of little avail because, to quote Müller, 'it is a mark that every artisan or apprentice - each having their individual mark - have to put on, in order to avoid that, when defects are made, they blame one another and quarrel'.[21]

The immortal mussel-painted pattern, let us not forget it, is not only aesthetically justified, it also serves the purpose of hiding blemishes occurring from metal impurities in the clay. The fascinating cobalt-blue mussel-decoration derives from Meissen, was copied by Fürstenberg, from whence it became the preferred Copenhagen pattern, so curiously enough British factories of Worcester, Caughley, Lowestoft and New Hall refer to it as the 'Copenhagen' pattern.[22] There was no end to imitation of design in the porcelain industries, and the original artist, if he did exist, was consigned to oblivion.

The subordinate position of art in relation to technology was never viewed as a fall by Müller. He considered himself a scientist, in fact he was a member of the Royal Society of the Sciences, and the supreme technical ruler of the factory. There was no aesthetic leadership. Müller did not want any. He did not want foreign expertise either, whether technological or artistic. When foreign artisans were imposed upon him he wanted them to educate Danish apprentices. Müller employed young boys of poor circumstances who would be happy to work in the factory. Orphans of soldiers and sailors were his favourites, provided they were disciplined. These apprentices would have no family nor friends to interfere in case of trouble. They would depend on Müller and his place for them in the division of labour. As opposed to expert artisans from abroad, these boys would not fancy themselves or get artistic ideas into their heads, nor conceive themselves indispensable to the factory, nor demand higher wages. They would all have to swear on the Bible to remain in the factory 'as long as God Almighty grant us the blessings of health to work' and never disclose any knowledge, 'but let it remain an eternal secret dying with ourselves. So help us God and His Holy Word!'[23]

Josiah Wedgwood distributed a pamphlet warning his workers against seduction.[24] He related a couple of deterrent case-stories about the ill fate of Staffordshire workmen having been bribed to go to America or France. One group was shipwrecked, another realised that the golden promises were never fulfilled. Wedgwood argued that England had the highest wages in the world, that arbitrary governments abroad would deprive English workers of their liberty at midnight and send them to prison, and that they would be visited by 'a disease of the mind, peculiar to people in a strange land; a kind of heart-sickness and despair, with an unspeakable longing after their native country, not to be described, and of which no one can have a just idea but those who have been under its influence'. Over and over again the source material refers to sentiments of patrotism, while the technologists of porcelain and pottery did their best to eliminate national borders of taste and market in pursuit of international competitiveness.

The very essence of this technology was reproduction. There were endless artistic objects to reproduce from and a number of techniques available to reproduce by. First we shall look at design, then at technology.

Factories all over Europe copied one another's products, as we have seen, but taste and composition of the consumer market were open to change. The fall of l'ancien regime was accompanied by a shift from aristocratic rococo to neoclassicism which appealed to bourgeois preference for the antiquity and universalistic ideas. At 'Etruria' antique design was copied unscrupulously, and Sir William Hamilton, excavating Pompeiï and Herculanum, was of great inspiration to Wedgwood and his partner, Thomas Bentley. Wrote the former to the latter, 'Do you really think we may make a complete conquest of France? My blood moves quicker ...Assist me my friend, & the victory is our own. We will make them (now I must say Potts, and how vulgar it sounds), I won't though, I say we will fashion our Porcelain after their own hearts, & captivate them with the Elegance and Simplicity of the Ancients...' Wedgwood proved as true a prophet as he could have hoped. Sèvres itself was soon copying the cameo-effects to be found in Wedgwood jasper.[25]

In Copenhagen there was no special artistic leadership as long as Müller was the leader, and decoration was inspired by a large collection of copperprints by Danish and European artists. After Müller an artistic leader was appointed. He changed the prevailing design from rococo to neoclassicism, and greatly contributed to the popularity of the products by introducing biscuit copies of Bertel Thorvaldsen's reliefs and figures, much to the satisfaction of the sculpturer himself. Thorvaldsen's art was in the international trend, and represented by no means a return to national design. There were, of course, limits to the use of foreign copperprints. English villages and landscapes, and German coats-of-arms had to be replaced by national equivalents, but that was no problem; interchangeable symbols were abundant in the collection of copperprints.[26]

There was one important national decoration, however, the 'Flora Danica', based on a complete scientific description of the flora of the realm, in Linnean order. This was a prestigious project intended as a gift for Empress Catherine II of Russia; it consisted of more than 1600 items, and was possibly also intended to be a lever to enter that market which had already been penetrated by another royal gift, a Wedgwood production comprising only 952 pieces, ornamented with views of English country houses.[27]

Except for these few, outstanding examples, the decorative designs were assuming universal application. So were, of course, the reproduction techniques. Most important of all were the moulds. At first iron moulds made by the iron foundries were used, but later on gipsum moulds were preferred, mainly because the gipsum sucks the water of the paste. There were several techniques for copying decorations. Transfer-printing was the most important. The picture was etched into a copperplate and from there the dye was transferred to the unglazed porcelain by a blotting paper. Another technique consisted in perforating a paper illustration and pour coal powder through the holes. A camera obscura could be used to project illustrations on paper or directly on the biscuit. But most common of all was the manual reproduction of the pattern by the brush. This method would cause minor differences between copies, but these had nothing to do with

Fig. 6. Bertel Thorvaldsen: Porcelain statuette of Lord Byron.
These were mass produced by moulding technique by Royal Copenhagen and marketed all over Europe.
Photograph by author. Royal Copenhagen Museum.

Fig. 7. Porcelain Statuette symbolizing Patriotic feelings.
Symbols of patriotism were made by many nations. It is somewhat ironic that a German model was copied and mass produced as a commodity embodying patriotic feelings for Denmark. Notice the difference between the two statuettes. One is finished. The other still bears the marks of the moulds.
Photograph by author. Royal Copenhagen Museum.

artistic performance. The ideal manual reproduction was completely anonymous. The fewer traces of the individual artisan the better. On the whole technologists of this period were preoccupied with reproduction techniques. James Watt invented a copying-machine in 1780 and was working for many years on a three dimensional copying-device, the 'Iconopia', to make scientifically accurate copies of living models. Eramus Darwin, like Wedgwood and Boulton a member of the Lunar Society, requested Watt to invent 'an Instrument to draw landscapes with'. All of these men would have marvelled at the audio- and video-reproduction machinery that belongs to our every day life.[28]

Müller and his successors did not at all view their neoclassical replica a crude plagianism of antique art. Quite the opposite. They found that their science-based technology marked the height of civilization, of which their antique patterns were only the initial steps taken by artisans. As they saw it modern porcelain technology deserved a status among the muses, or even higher, because their products were more perfect, more uniform and accessible to more people. Standardized mass consumergoods would exist in surroundings that were completely different from those of the original creation, but exactly that was an expression of human progress: science and technology were masters beyond time and space.

In conclusion, let me give just one example of this. It is well known that Sir William Hamilton's wife was the mistress of Lord Nelson. Following the battle of Copenhagen in 1801, Nelson wrote the following lines to Emma Hamilton: 'My dearest friend, I can get nothing here worth your acceptance, but as I know you have a valuable collection of china, I send you some of the Copenhagen manufacture. It will bring to your recollection that here your friend Nelson fought and conquered... Ever yours, Nelson'.[29] The Hamilton collection expressed not only the suspension of time and space. It also bridged the gap between technology and the decorative arts.

The marriage between the arts and technology was itself an integral part of the industrial revolution. The way it took place, I would recommend, ought to be termed exchange of culture (in its broadest sense) rather than transfer of technology as we usually define it, because it is hardly possible to distinguish the predator from the victim.

NOTES

[1] [Born 1941 in Copenhagen. Graduated from the University of Copenhagen 1970. Lecturer at the University of Roskilde from 1972. Assistant professor since 1976. His work has concentrated on teacher education (history) and internationalisation of university courses. His research has been in the history of ideas, history of agriculture and history of science and technology. From 1990 head of the TISC group (Technology, Innovation, and Society in a Cultural perspective, set up by the National Research Council) writing a 3-volume Danish History of Technology 1750-1990. Has published on the history of education, history of ideas, history of science and technology (particularly Grundtvig, Oersted, steam engines, agriculture, canals, metallurgy).]

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LENNART SCHÖN

Elektriciteten i svensk industri under hundra år

Få skulle förneka att elektriciteten haft stor betydelse för svensk industriell utveckling under det gångna seklet. Sedan den moderna industrins genombrott har elanvändning och elektroteknik varit framträdande drag i svensk industri. Bakgrunden är väl känd. Sverige hade flera energikrävande industrier och vattenkraft men saknade fossila bränslen. Under 1890-talet uppstod ett utvecklingsblock med elproduktion, elektroteknisk utrustning och elanvändning inom industrin som kom att utgöra en drivkraft i det industriella genombrottet och påverka svensk industristruktur under 1900-talet. Elektricitet och elektroteknik har vägt tyngre i energianvändning och produktionsinriktning i Sverige än i flertalet andra industriländer.

Frågan i denna artikel är vilken långsiktig betydelse elektriciteten haft för svensk industriell utveckling - och vilken betydelse den kan få framöver.[1]

Industriell utveckling och elanvändning - några utgångspunkter

Industriell utveckling innebär att industrins produktionsresurser ger ett växande utbyte, dvs att produktiviteten stiger. Sedan 1890 har arbetsproduktiviteten ökat med drygt 3,5 procent om året. Produktionsvolymen per arbetstimme är idag 50 gånger större än för hundra år sedan. Effektivare produktionsutrustning och mer energi har ställts till arbetets förfogande; mängden energi per arbetstimme har vuxit med 1,5 procent årligen. Samtidigt har förnyelsen av industrins produktionsinriktningar varit omfattande. Nya branscher, nya produkter och nya kvaliteter har utvecklats. Framför allt har nya produkter och nya metoder ställt högre krav på insatserna av kunskap men inneburit mindre energikrävande bearbetning av råmaterial. Effektivitetsökning och förnyelse är två grundläggande inslag i den industriella utvecklingen.

Mönster i industriell utveckling

För att uppnå effektivitetsökning och förnyelse krävs investeringar men investeringarna är i hög grad av olika slag. Ökad effektivitet inom en verksamhet uppnås genom att kostnaderna sänks per producerad enhet med rationaliseringsåtgärder som mekanisering, automatisering, koncentration och specialisering. Investeringarna består då till stor del av ny utrustning inom givna anläggningar och de kan på ganska kort sikt ge högre produktivitet.

Förnyelsen kräver däremot mera långsiktiga investeringar. Nya anläggningar behöver byggas, helt ny utrustning tas i anspråk, ny kunskap användas etc. Ofta är också en framgångsrik förnyelse beroende av utvecklingen på många andra områden - nya marknader, kompletterande branscher, ny infrastruktur etc. Omfattande förnyelse, som berör många områden av industrin och samhället, kan sammanfattas med begreppet *utvecklingsblock*.[2]

I centrum för utvecklingsblocket står innovationen. Grundläggande sådana skapar nya behov och nya möjligheter. Innovationerna kräver nya kunskaper och nya kvaliteter hos insatsvaror, maskinutrustning och anläggningar. De är beroende av ny organisation i distribution och av nya beteenden hos användarna. Samtidigt möjliggör innovationsspridningen stora förändringar i andra verksamheter. Komplementariteten mellan olika delar i blocket har starkt expansiva effekter, där brister och obalanser uppstår vilka kan avhjälpas med investeringar och rörlighet i resursallokeringen. När komplementariteten mellan de olika delarna ökar och expansionsutrymmet avtar, tilltar konkurrensen. Investeringarna blir då mera inriktade på att stärka konkurrenskraften genom rationaliseringar.

Konkurrenskraft och utvecklingskraft förutsätter varandra, men samtidigt finns en konflikt mellan att satsa på omedelbar effektivitetsökning och mera långsiktig förnyelse. Förmågan att uppnå ökad effektivitet och förmågan till förnyelse behöver inte gå hand i hand. Detta gäller inte bara inom enskilda verksamheter utan också på ett mera generellt, makroekonomiskt plan. Tidigare forskning om svensk strukturell förändring sedan industrialiseringen fram till idag har visat att förnyelse och effektivitetsökning omväxlande satt sin prägel på utvecklingen.[3]

Sedan mitten av 1800-talet har svensk ekonomi präglats av trendväxlingar i några centrala variabler som tillsammans bildar ett tydligt mönster. Tre längre perioder, avgränsade av strukturkriser på 1890-, 1930- och 1970-talen, har kunnat iakttas. På ett generellt plan har samma utvecklingstendenser återkommit under dessa perioder. Efter kriserna har följt en fas på 15-25 år, då investeringarnas andel av totala inkomster stigit starkt. Särskilt har långsiktiga investeringar i byggnader och anläggningar inom industri och infrastruktur ökat. Inom industrin har företagsbildningen varit livlig. Efterfrågetrycket i ekonomin har höjts - inte minst på krediter - och inflationstakten stigit. Denna svenska utveckling har haft sin motsvarighet internationellt och förnyelsen har präglat utvecklingen på många områden. Efter ett tiotal år har strävandena efter integration i en förändrad värld tilltagit och tillväxten har kulminerat. Därpå har följt en period på 10-15 år med omvända förtecken. Med ökande konkurrens och specialisering har investeringarna alltmer inriktats mot maskiner, dvs mot mera kortsiktigt inriktade åtgärder för att öka effektiviteten inom existerande anläggningar. Samtidigt som prisnivån stabiliserats, har rationaliseringar och koncentration tilltagit. Denna utveckling har löpt fram till en ny strukturkris.

Växlingarna mellan expansiv förnyelse och strukturomvandling respektive konsoliderande effektivitetsökning och rationalisering kan iakttas bl a genom mätningar av produktivitetsförändringen. Under perioder av strukturomvandling har s k överföringsvinster - dvs snabbare tillväxt för branscher med relativt hög produktivitet - varit betydande, medan å andra sidan produktivitetsökningen inom branscherna varit relativt låg. Det omvända gäller för perioder av strukturrationalisering, som präglats av relativt små skillnader mellan branschernas tillväxttakter men av hög produktivitetsökning inom branscherna.

Tabell 1 Årlig procentuell förändring i arbetsproduktiviteten inom branscher (a), som resultat av förändringar i branschstruktur (b) och omallokeringens andel av total produktivitetsökning (c) samt årlig procentuell förändring i sysselsättningen för arbetare (d) och tjänstemän (e) inom svensk industri 1890-1987.

	a	b	c	d	e
1890-1910	2,0	0,6	0,23	3,3	6,6
1910-1933	2,6	0,1	0,04	0,2	2,1
1933-1954	1,8	1,1	0,38	1,6	5,6
1954-1973	5,9	0,5	0,08	- 1,1	1,4
1973-1991	2,8	0,7	0,20	- 2,8	- 1,5

Källa: Lennart Schön 1990: Elektricitetens betydelse för svensk industriell utveckling. Vattenfall U(S) 1990/60 och SCB: Statistiska meddelanden.

Också sysselsättningens förändring visar likartade systematiska växlingar. Under omvandlingsperioderna har således de mera expansiva investeringarna i kapacitetsökning lett till hög tillväxt i sysselsättningen. Förnyelsen har dessutom i synnerhet ökat efterfrågan på arbetskraft med ny kompetens och tillväxten har varit särskilt stark för tjänstemännen. Under rationaliseringsperioderna däremot har åtgärderna för effektivitetsökning hållit tillbaka efterfrågan på arbetskraft varför sysselsättningsökningen varit svag både för arbetare och tjänstemän.

Detta mönster visar sig också i förhållandet mellan relativt tjänstemannaintensiva och relativt arbetarintensiva branscher. Under omvandlingsperioderna har branscher med starkast tillväxt också haft en högre andel tjänstemän än genomsnittet. Detta har varit ett inslag i strukturomvandlingen. Under rationaliseringsperioderna har däremot de systematiska skillnaderna i detta hänseende varit små. Branscherna har då utvecklats mera likartat, vilket kan vara uttryck för att förnyelsen standardiserats.

Också under den senaste perioden från 1970-talet har produktivitetsökningen inom branscherna varit relativt svag men överföringsvinsterna betydande. Merparten av denna omallokering inträffade under åren 1988-1991. Förmodligen har den fortsatt under åren 1992 och 1993. Detta stämmer överens med ett tidigare historiskt mönster. Under tidigare omvandlingsperioder har nämligen omallokeringen av arbetskraft till nya tillväxtbranscher med högre produktivitet varit koncentrerad till en senare del av omvandlingsperioderna - dvs till nedgångar i expansiva *long swings* kring 1910 resp 1950. Den starkare omvandlingen med utslagning av "gamla" kombinationer har alltså försiggått under tider av kärvare villkor med förlängda konjunkturnedgångar. Då har också exportens betydelse ökat och ett nytt specialiseringsmönster uppstått som blivit en stomme i en kommande tillväxt. Den historiska erfarenheten tyder alltså på att de som talat om svag omvandling under 1980-talet varit alltför tidigt ute i den bedömningen.

Den senaste perioden avviker dock från tidigare omvandlingsperioder genom att sysselsättningen för både arbetare och tjänstemän minskat samt genom att skillnaden i gruppernas utveckling varit liten. Ett skäl till det senare förhållandet kan vara att industrianknutna tjänster, därför att de varit expansiva, alltmer utförts av självständiga företag som statistiskt redovisats inom tjänstesektorn. Det innebär i så fall att industrisysselsättningen ger ett sämre mått än tidigare på omvandlingen i den industriella verksamheten.

Frågan för den fortsatta analysen är om eltillgång och elanvändning varit delaktiga i industrins långsiktiga förändringsmönster och vilka samband som funnits mellan elektriciteten, å ena sidan, och industrins förnyelse och effektivitetsökning, å andra sidan. I ett långsiktigt perspektiv spelar förmågan till framgångsrik förnyelse en strategisk roll och sambanden mellan elektriciteten och industrins förnyelse är därför av allra största vikt för analysen.

Det råder ingen tvekan om att god tillgång på energi gynnar effektivitetsökning, medan dess inverkan på den industriella förnyelsen är mera diskutabel. En effektivare resursanvändning skapar tillväxt och utrymme för förnyelse. Låga energipriser kan emellertid gynna traditionell energikrävande råvaruorientering framför förnyelse. De kan också öka överlevnadsförmågan hos sådan tillverkning, som möter skärpt konkurrens och förändrade villkor med kostnadssänkning och rationalisering snarare än med utveckling av produkter och kunskap.

Elektriciteten har emellertid en rad egenskaper både på användningssidan och på tillgångssidan som skiljer den från andra energibärare. Dessa egenskaper spelar stor roll för analysen av elektricitetens samspel med den industriella utvecklingen.

Elektricitetens egenskaper

Från användarens utgångspunkt kan elektricitetens egenskaper uttryckas som en uppsättning fördelar gentemot mekanisk kraft eller bränslen. Användningen av elektriciteten är flexibel. Den kan lätt fördelas mellan olika anläggningar och inom en anläggning i valfria mängder till olika ändamål. Den kan omvandlas till mekanisk, termisk och kemisk energi. Med stor noggrannhet kan den regleras och den ger ökade möjligheter att kontrollera produktionsprocesser. Kapitalbehovet minskas genom att den kan ersätta kraftmaskiner och den ger i jämförelse med bränslen eller mekanisk kraft en renare arbetsmiljö med mindre buller eller avgaser.

Elektriciteten har främst en nackdel. Omräknat efter energiinnehåll är den dyrare än andra energibärare. Det är naturligtvis logiskt, eftersom elektriciteten är en förädlad energiprodukt - energin i alla andra energibärare kan omvandlas till elektricitet. Prisdifferensen mellan elektricitet och andra energibärare har varierat i storlek, men den har hela tiden funnits. Differensen har emellertid varit mindre i Sverige än i flertalet industriländer.

Elektriciteten har alltså högre kvalitet än andra energibärare. Ett fullt utnyttjande av elektricitetens egenskaper kräver då att den industriella tekniken, organisationen och produktinriktningen utvecklas så att dessa egenskaper tas tillvara. Man kan hävda att ju större vikt som läggs vid flexibilitet, kontroll och miljö i den industriella produktionen, desto starkare blir elektricitetens konkurrenskraft gentemot andra energibärare.

Elektriciteten har emellertid också egenskaper på utbudssidan, som skiljer den från andra energibärare. Produktionen och distributionen av elektricitet är kapitalintensiv, har stordriftsfördelar och ger ett stort utrymme för teknisk förändring. Till höga anläggningskostnader och låga driftskostnader kommer att elektriciteten inte kan lagras, varför systemet är beroende av ständig balans mellan produktion och konsumtion. Följaktligen kan kostnaden per KWh falla vid utvidgade system och hög konsumtionsnivå. Detta skapar förutsättningar för en stark ömsesidig påverkan mellan produktions- och användningssida. Ökad elanvändning skapar utrymme för utbyggnad med möjlighet till fallande priser; utbyggnad med fallande priser kan - om detta samverkar med den industriella utvecklingens riktning - leda till kraftigt ökad användning.

Elkraftssektorns egenskaper kan ses från två håll. Å ena sidan skapar de en systembundenhet, som är motsatsen till den flexibilitet som präglar elanvändningen. Elkraften blir en del av den samhälleliga infrastrukturen med den kombination av stabilitet och tröghet som kännetecknar sådan. Å andra sidan ger elkraftsektorns dynamiska potential ett stort utrymme för samspel med både den industriella utvecklingen och den bredare samhällsutvecklingen.

Detta samspel kan ges ett samlat perspektiv med begreppet utvecklingsblock. Elektriciteten är en grundläggande innovation, som påverkar alla delar av samhället och som ingått i skilda utvecklingsblock under det gångna seklet. Gemensamt för dessa har varit att den elektrotekniska industrin stått i centrum med länkar till kraftindustrin, till industrins elanvändning och till elanvändningen utanför industrin.

Den primära frågan är vilken betydelse dessa utvecklingsblock kring elektriciteten haft för den industriella utvecklingskraften historiskt och vilken betydelse de kan ha idag. Frågan skall först behandlas i ett makroekonomiskt perspektiv på elanvändning, elpriser och industriell utveckling, där resultaten samlas i en strukturmodell, och därefter i en historisk förloppsanalys.

Trender i elanvändning, priser och industriell utveckling sedan 1890

Industrins elanvändning

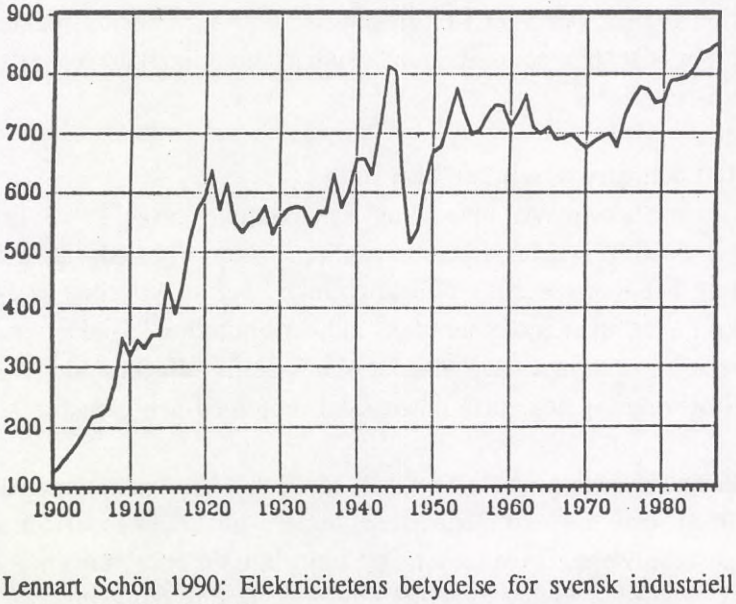
Under hela den moderna industriella utvecklingen har effektiviteten i energianvändningen ökat. Den *specifika energianvändningen* (använd energi i förhållande till förädlingsvärdet i fasta priser) har fallit med i genomsnitt 2 procent om året sedan 1890-talet. Samtidigt har den *specifika elförbrukningen* ökat med cirka 1,5 procent årligen. Elektricitetens andel av industrins energianvändning har alltså vuxit ihållande och uppgår idag till cirka 50 procent (räknat efter energibärarnas energiinnehåll).

Tabell 2 Årlig procentuell förändring i den specifika elförbrukningen (a) och i den specifika förbrukningen av övriga energibärare (b) samt i elektricitetens andel av energianvändningen (c) inom industrin 1900-1987.

	a	b	c
1900-1920	+7,2	- 2,2	+0,4
1920-1935	- 0,4	- 2,7	+0,2
1935-1955	+0,9	- 2,3	+0,5
1955-1975	- 0,3	- 1,6	+0,2
1975-1987	+1,1	- 5,8	+1,6
1900-1987	+1,4	- 2,1	+0,4

Källa: Lennart Schön 1990: Elektricitetens betydelse för svensk industriell utveckling. Vattenfall U(S) 1990/60.

Diagram 1 Specifik elförbrukning i svensk industri 1890-1987. Fast branschstruktur. MWh per miljoner kr förädlingsvärde i 1969/70 års prisnivå.



Källa: Lennart Schön 1990: Elektricitetens betydelse för svensk industriell utveckling. Vattenfall U(S) 1990/60.

Den ökade elförbrukningen har emellertid varit en markant diskontinuerlig process och följt ett trappstegsliknande förlopp, vilket framgår av tabell 2 och diagram 1. Under tre perioder om vardera cirka 20 år har elförbrukningen ökat betydligt snabbare än industriproduktionen - 1900-1920, 1935-1955 och från 1975. Ökningstakten var, naturligt nog, särskilt hög under elektricitetens introduktionsfas som sträckte sig fram till åren efter första världskriget. Speciellt kraftigt ökade då förbrukningen inom den energitunga delen av industrin. Därefter förblev relationen mellan elförbrukning och produktionsvolym på en i stort sett konstant nivå under cirka 15 år. En ny period av ökning inleddes vid mitten av 1930-talet. I samband med andra världskriget var fluktuationerna starka - bl a beroende på kraftiga variationer i produktionsvolymen och på inslag av mera tillfälliga elkrävande ersättningsprodukter - men efter kriget fortsatte en mer stabil ökning fram till mitten av 1950-talet. Framför allt steg då den energilätta industrins elförbrukning starkt. Därefter följde ånyo en period på cirka 20 år av i det närmaste konstant specifik elförbrukning fram till en tredje period av ökande specifik elförbrukning som inleddes på 1970-talet. Återigen dominerade då ökningen inom den energilätta industrin.

Mönstret är alltså klart. Markanta ökningar i elförbrukningen har inträffat under perioder på cirka 20 år, vilka följts av ungefär lika långa perioder med en konstant specifik elförbrukning. Detta är ett grundläggande resultat av analysen. Man kan då fråga om "trappstegen" i industrins elförbrukning orsakats av periodiska förändringar i eltillgång och elpriser eller av liknande förändringar inom industrin som påverkat elektricitetens konkurrenskraft gentemot andra energibärare.

Elektriciteten och förnyelsen har hört ihop

Mönstret i elförbrukningens utveckling sammanfaller mycket väl med det strukturella mönstret i ekonomins utveckling. Under perioderna av strukturomvandling har den specifika elförbrukningen och elektricitetens andel av energianvändningen ökat inom samtliga industribranscher. Under strukturrationaliseringen har däremot både elandel och specifik elförbrukning varit stabil. Ökad elförbrukning hör alltså tidsmässigt ihop med den industriella förnyelsen.

Men sambandet mellan elektricitet och förnyelse har varit starkare än så. Branscher med den starkaste tillväxten under omvandlingsperioderna har också haft en relativt hög kvot elektricitet/bränsle i sin energianvändning - de har alltså företrädesvis använt eltekniska system. Under rationaliseringsperioderna har däremot inga systematiska skillnader förlegat mellan relativa tillväxttal och elandelar i energianvändningen.

Det finns således en klar parallell mellan relationerna el/bränsle och tjänstemän/arbetare i förhållande till omvandling och rationalisering. Omvandlingsperioderna har inneburit förnyelse inom industrin med ökande investeringar i nya anläggningar och företag, med växande sysselsättning i synnerhet av tjänstemän och av ökad specifik elförbrukning. Denna utveckling har skett inom samtliga branscher, men den har varit särskilt stark inom tillväxtbranscherna, dvs inom de branscher där förnyelsen haft sitt centrum. Tillväxtbranscherna har dessutom haft en relativt hög produktivitet, medan ökningstakten i produktiviteten inom branscherna generellt sett varit svag.

Slutsatsen är därför att den industriella förnyelsen lett till att efterfrågan skiftat mot arbetskraft med ny kompetens och mot energibärare med hög kvalitet, dvs i första hand mot elektricitet. Denna har varit komplementär till den industriella förnyelsen.

Frågan kvarstår emellertid i vilken utsträckning förändringar i eltillgång och övrig energitillgång varit delaktiga i att utforma "trappstegen" i industrins elektrifiering.

Prisutvecklingen på elektricitet och bränslen

Långsiktigt har elektriciteten blivit allt billigare jämfört med merparten av industrins produkter och framför allt i jämförelse med bränslen av skilda slag. I förhållande till prisindex för industriprodukter har sedan 1890-talet elpriset fallit med i genomsnitt 1.5 procent årligen, medan bränslepriserna stigit i samma takt. I förhållande till bränslepriserna har elpriset således fallit med 3 procent årligen.

Tabell 3 Årlig procentuell förändring i elpris (a) och bränslepris (b) relativt industriproduktprisindex samt i elpris relativt bränslepris (c) 1893-1987.

	a	b	c
1893-1915	- 4,8	0,8	- 5,8
1915-1930	1,1	- 4,5	5,7
1930-1950	- 3,1	4,0	- 7,0
1950-1970	0,7	- 2,0	2,7
1970-1987	- 0,8	6,9	- 7,8
1893-1987	- 1,5	1,5	- 3,1

Källa: Lennart Schön 1990: Elektricitetens betydelse för svensk industriell utveckling. Vattenfall U(S) 1990/60.

Den långsiktiga utvecklingen är knappast anmärkningsvärd. Prisfallet på elektriciteten är typiskt för en expansiv innovation knuten till ett system med stordriftsfördelar och med stort utrymme för teknisk förändring. Men det är mycket anmärkningsvärt att relativt elpris och relativt bränslepris (gentemot industriprisindex) konsekvent utvecklats i motsatta riktningar. Prisfallet på elektricitet och prisstegringen på bränslen har nämligen varit koncentrerade till de tre tidigare konstaterade perioderna om vardera cirka 20 år. Under dessa perioder föll således elpriset synnerligen kraftigt gentemot bränslepriser! Under mellanperioderna, som varit ungefär lika långa, har samtliga relativpriser gått svagt i motsatt riktning.

Återigen framträder alltså samma tidsmässiga mönster som för industrins elförbrukning och strukturella utveckling. Under de perioder, då elförbrukningen ökat markant och den industriella förnyelsen varit stark, har elpriset fallit gentemot industriprodukternas priser och mycket kraftigt gentemot bränslepriser. Prisutvecklingen ger således tydligt belägg för att också förändringar i eltillgången inverkat på "trappstegen" i industrins elförbrukning.

De relativa prisfallen för elektriciteten sammanfaller med de stora utbyggnadsperioderna för kraftindustrin. Från 1890-talet t o m tiden för första världskriget skedde utbyggnaden av vattenkraften i södra och mellersta Sverige med en tilltagande integration av elnätet - krönt av stamlinjen mellan Älvkarleby och Trollhättan som förband södra och mellersta Sveriges elsystem. Från mitten av 1930-talet till början av 1950-talet togs det andra stora steget med utbyggnaden av övre Norrlands vattenkraftsresurser, vilka knöts samman med det nationella nätet genom linjen mellan Harsprånget och Hallsberg. Under 1970-talet utvecklades kärnkraften som det senaste stora steget i elkraftsproduktionen. Gemensamt för dessa utbyggnadsfaser är att stordriftsfördelar och teknisk förändring kunnat utnyttjas i både produktion och distribution av elkraften.

Elkraftssektorns språngartade utveckling under strukturomvandlingsperioderna och dess särpräglade utbudsfunktion bildar en bakgrund till det relativa prisfallet på elektricitet. Prisfallet ingår emellertid också i ett bredare sammanhang på prisutvecklingens område.

De periodiska växlingarna för elpriset sammanfaller med växlingar i trenden för den allmänna prisnivån. Under de perioder, som relativpriset på elektriciteten fallit, har den allmänna prisutvecklingen präglats av inflation, medan perioderna av relativ prisstegring för elektriciteten haft en ganska stabil eller t o m fallande allmän prisnivå. Omvänt kan sägas att bränslepriser i mycket hög grad gett uttryck för den allmänna prisutvecklingen.

Dessa trendväxlingar i relativprisernas utveckling har inte varit en enbart svensk företeelse. Man kan notera att växlingarna stämmer nära överens med den periodisering för prisförhållandet mellan råvaror och industriprodukter på världsmarknaden, som Rostow presenterat.[4] Medan priserna för bränslen som ved, kol och olja uppträder som mycket typiska företrädare för råvarupriser, visar elpriset å andra sidan i extremt hög grad utvecklingen för industriprodukter.

Analysen visar således på anmärkningsvärda likheter i de långsiktiga systematiska trendväxlingarna för ekonomins och industrins strukturutveckling, industrins elförbrukning, tillgången på elkraft, allmän prisnivå och relativa priser. Dessa förlopp kan självfallet inte förklaras utifrån enskilda faktorer utan skall samlas och analyseras inom det mönster för långsiktig strukturell utveckling, som tidigare presenterats.

Elektriciteten i ett strukturellt mönster

Under strukturomvandlingen har behovet av nya industrianläggningar ökat. Nya anläggningar skapar större utrymme för nya energisystem samtidigt som tillväxten för nya branscher, nya produkter och nya kvaliteter skiftar efterfrågan. Denna går mot energibärare med hög kvalitet i fråga om kontroll och flexibilitet i användningen. Också behoven av ny infrastruktur som kommunikationer, bostäder och system för energiförsörjning har ökat. Utbyggnaden av elkraften har utgjort en del av de expansiva infrastrukturella investeringarna och mellan förnyelsen inom industri och elsektor har funnits direkta band. Den elektrotekniska industrin har under samtliga omvandlingsfaser varit en av de centrala tillväxtbranscherna inom industrin. Relativpriset på elektroteknisk utrustning har då fallit kraftigt. Detta gäller, som visats ovan, också för elektriciteten.

Medan de relativa prisfallen för elektricitet och elektroteknisk utrustning har sin bakgrund i kapacitetsuppbyggnad och innovationsverksamhet, bidrar förnyelsen samtidigt till en allmän prisökning. Spridningen av nya utvecklingsblock leder till förskjutningar i efterfrågan mot nya insatsvaror och mot kompletterande behov, där bristsituationer uppträder med prisstegring som följd. Ytterligare kapacitetsökande investeringar krävs. Långsiktiga investeringar höjer därför efterfrågan på krediter och inför de möjligheter och behov, som omvandlingen för med sig, har banker och stat bedrivit en mer expansiv kreditpolitik. Detta har ökat penningmängden i ekonomin.[5] Till en del har kreditexpansion finansierat den kapitalkrävande utbyggnaden av elkraften och industriella förnyelsen. Kapacitetsökningen och förnyelsen har också lett till ökad efterfrågan på arbetskraft med ny kompetens. Men det tar tid att få nya system att fungera effektivt, varför produktivitetsökningen varit svag under dessa perioder. Investeringarna, efterfrågeökningen och den eftersläpande produktiviteten har lett till stigande prisnivå.

När anläggningar och infrastruktur byggs ut har efterfrågan ökat på energitunga produkter såsom stål och cement, på råvaror, på transporter och på bränslen. Men alla dessa produktionsområden är kapitalintensiva och därför trögrörliga. Det tar tid att öka produktionskapaciteten, varför relativpriset på råvaror, bränslen, transporter och tunga industriprodukter stiger. Efterfrågeförskjutningarna stimulerar världshandeln och leder till en geografisk vidgning av råvaruproduktion och industrialisering. Under omvandlingsfaserna har således nya nationer dragits med i den industriella utvecklingen. Kapacitetsökande investeringar inom infrastruktur, råvaruproduktion och tung industri i nya industriländer leder då till att behoven av transporter, råvaror och energi ökar ytterligare. Den expansiva omvandlingsfasen kan sägas kulminera.

Med en utbyggd infrastruktur och utökad bränsleproduktion faller transportkostnaderna och den internationella integrationen ökar - till detta har också institutionella åtgärder för att sänka transaktionskostnaderna bidragit. Medan konkurrensen skärps, avtar de expansiva anläggningsinvesteringarna. Samtidigt som kapacitetsökningen varit betydande, försvagas efterfrågan på energitunga produkter. Priset faller på bränslen, råvaror, stål etc och strukturproblem inom de tunga branscherna börjar uppträda. Den ändrade investeringsinriktningen mot maskiner är gynnsam för verkstadsindustrin, men även denna är nu utsatt i en hårdare internationell miljö. Det skärpta konkurrensläget möts med ökad mekanisering, automatisering, koncentration och specialisering. Rationaliseringen och ett effektivt fungerande samband med en utvecklad infrastruktur leder till stora produktivitetsökningar.

Produktivitetsökning och intensifierat utvecklingsarbete skapar utgångspunkter för ny expansion och nya utvecklingsblock. Ny teknik tas i anspråk inom gamla anläggningar för att sänka kostnaderna och stärka konkurrenskraften. Samtidigt leder produktivitetsökningen till stigande reala inkomster och konsumtionsutrymmet ökar i ett läge då investeringarnas andel av totala inkomster stagnerar. Radikala nya livs- och konsumtionsmönster utvecklas tillsammans med en modernisering av hela samhället. Som ett inslag i denna modernisering har elförbrukningen ökat starkt utanför industrin.

Grunden för kommande utvecklingsblock kring elkraften har då lagts både inom och utom industrin. Under 1880-talet infördes elbelysning i städer och i fabriker, vilket bl a möjliggjorde skiftarbete, samtidigt som tekniken för trefas växelström utvecklades. Under 1920-talet infördes eldrift av specialmaskiner efter "amerikanska metoder", medan eldrivna hushållsapparater introducerades på marknaden och utvecklingsarbetet för högspänd elkraftsöverföring pågick. Under 1960-talet kom processtyrning och automatisering att användas alltmera i kombination med elektronik samtidigt som kärnkraften utvecklades.

Strukturproblemen har under tiden tilltagit, speciellt för de tunga industrierna. En bidragande orsak har varit att nya industriländer ökat sin produktionskapacitet och - med försämrade terms-of-trade - blivit alltmer skuldbelastade och därmed beroende av exportframgångar på sviktande marknader. Strukturella och finansiella obalanser har vävts samman och utlöst strukturkrisen - en kris som i sin tur öppnat vägen för strukturell och institutionell förändring och därmed för en period av expansion.

Detta är en historia som i sina huvuddrag upprepat sig. Den historiska dräkten har naturligtvis skiftat och Sveriges position förändrats. På 1890-talet var Sverige en nyindustrialiserande stat som tog språnget upp till den utvecklade industrivärlden, på 1970-talet var Sverige en av de industrinationer som drabbades hårdast av kris- och stagnationsfenomenen. Men modellen ger utgångspunkterna för en förloppsanalys av elektricitetens förhållande till den industriella utvecklingen sedan 1890-talet.

Elektriciteten i den industriella utvecklingens förlopp

Elektricitetens genombrott från 1890-talet

Fram till 1880-talet hade svensk industri till stor del utvecklats på landsbygden nära råvaru- och energitillgångar såsom järnmalm, skog och vattenkraft. Under 1880-talet började dock städerna att växa snabbare och en mera sofistikerad industriproduktion utvecklades bl a inom elektroteknik, medan den traditionella järnhanteringen hade stora strukturproblem. Under 1890-talets inledande krisår (den s k Baringkrisen) skedde genombrottet för elektriciteten som drivkraft för tyngre processer med tekniken för trefas växelström. Därefter kom tillväxten att följa de nya banorna. Tiden från 1890-talet till första världskriget blev det moderna industrisamhällets genombrottsperiod i Sverige. Nya tillväxtbranscher framträdde, ny teknik infördes, den sociala situationen förändrades och nya institutioner tog ledningen. Elektriciteten var i hög grad del i detta skeende.

I inledningen dominerades elektrifieringen av den tunga industrin. Dess anläggningar låg nära vattenkrafttillgångar och energibehoven var så stora att kraftverk kunde byggas innan ett mera omfattande distributionsnät utvecklats. Nya möjligheter för kraftförsörjning till gruvor och stålverk skapades genom elektriciteten. Elektrifieringen kom också att öppna expansionsvägar för nya kraftkrävande industrigrenar som massa- och pappersindustrin och den kemisk-tekniska industrin.

Elektrifieringen innebar en kraftsamling med de aktörer och institutioner inblandade, vilka skulle komma att sätta sin prägel på det moderna industrisamhällets frammarsch.[6] Stor betydelse hade teknikutvecklingen - med anpassning av nya rön till den svenska industrins behov - inom framför allt det nybildade ASEA och det risktagande som Stockholms Enskilda Bank stod för. Efter hand kom också staten genom Riksgäldskontorets utlandsupplåning och Vattenfalls verksamhet att ta en allt aktivare del i elkraftssektorns utveckling. Denna kraftsamling kan poängteras särskilt med tanke på den konkurrenssituation som förelåg inom elektrotekniken - tyska företag som AEG och Siemens såg Skandinavien som en naturlig marknad - och med tanke på de stora kapitalbehov som en samtidig utveckling av produktion, distribution och användning av elektriciteten medförde. På kort tid ryckte svensk ekonomi fram till en position nära täten inom elproduktion och elektroteknik. Detta hör till den svenska industrialiseringens mera märkvärdiga bedrifter.

Med kraftindustrins och den elektrotekniska industrins utveckling skapades under åren kring sekelskiftet förutsättningar för en vidgad elektrifiering. Inom loppet av cirka 10 år halverades relativpriset både på elektricitet och på elmotorer.[7] Därigenom kom elektriciteten att påtagligt understödja den strukturomvandling som skjutit fart från mitten av 1890-talet med ny lokalisering av industrin, ny organisation och ny produktinriktning också inom den energilätta industrin. Genom elektriciteten ökade flexibiliteten i industrins lokalisering och industristädernas tillväxt tilltog. Dessa erbjöd växande marknader för nya konsumtionsvaruindustrier och för maskinindustrin. Städerna erbjöd också en ny arbetsmarknad, då de koncentrerade ännu knappa resurser av kunnande i modern industriell teknik. Genom koncentrationen kunde kunskapen utnyttjas effektivare och utvecklingsblockets olika möjligheter snabbare tas i anspråk.

Också inom industrianläggningarna skapades nya förutsättningar genom elkraften. Med den mekaniskt överförda kraften hade transmissionsanordningarna dominerat fabriksbyggnaden, begränsat organisations- och utbyggnadsmöjligheter och lett till olycksfall, buller och smuts. Med elektriciteten kunde mekanisering och specialisering drivas längre samtidigt som fabrikerna kunde anläggas friare och ljusare.

Detta skedde dock inte i ett enda slag. I början installerades elmotorer främst som komplement till tidigare kraftmaskiner, med fortsatt mekanisk kraftöverföring till de olika arbetsmaskinerna. Men med ökad tillit till den nya tekniken, med ökad eltillgång och nya elmotorer utvecklades s k gruppdrift. Den innebar att en enda elmotor försåg en grupp av funktionellt relaterade maskiner med kraft. Men det var först med enkeldrift, alltså en elmotor till varje arbetsmaskin, som elektricitetens fulla potential utnyttjades. En helt genomförd enkeldrift krävde emellertid utveckling av eltillgång och elmotorer liksom att nya fabriksanläggningar uppfördes.

Under 1920-talet skärptes konkurrensen internationellt med växande strukturproblemen. Särskilt besvärligt blev läget för mera infrastrukturellt inriktade branscher såsom stålverk och sågverk. Industrins åtgärder inriktades alltmer mot rationalisering, specialisering och standardisering.

Med en ökad effektivitet och färre nyanläggningar kom ökningen i industrins specifika elförbrukning att upphöra. Men genom den industriella utvecklingen sedan sekelskiftet och den under 1920-talet stegrade produktiviteten steg hushållens inkomster. Fram till omkring 1920 hade industrin helt dominerat inom elförbrukningen, men nu ökade användningen också inom andra områden och 1920-talet blev en period av samhällsmodernisering. Sålunda inleddes en mera allmän elektrifiering av järnvägarna och även hushållens elanvändning ökade, främst för belysningsändamål.

Samtidigt bedrevs ett intensivt utvecklingsarbete på flera områden för elproduktion och elanvändning - inom tekniken för kraftöverföring, inom metallurgi, motorer, maskiner och hushållsapparater. Grunden lades för en ny expansiv omvandling av samhällsekonomi och industri.[8]

Elektrifieringens andra våg från 1930-talet

Med uppgången ur 1930-talet kris inleddes den andra stora perioden av elkraftsutbyggnad och ökad elanvändning inom industrin. Elektrifieringen och den industriella förnyelsen knuten till elkraften gav nya expansionsvägar, vilket var ett av skälen till att svensk ekonomi klarade sig snabbare ur krisen än andra industriländer. Elektrifieringen och förnyelsen kom att sätta sin prägel på utvecklingen fram till mitten av 1950-talet.

Denna andra våg av elektrifiering kom i många avseenden att fullborda den utveckling som inletts kring sekelskiftet. Ett verkligt nationellt elnät skapades genom att övre Norrlands kraftresurser byggdes ut samtidigt som distributionen förbättrades avsevärt också på landsbygden. Den elektrotekniska industrin kom därvid att stå i centrum för utvecklingen i två avseenden. Å ena sidan krävde de stora avstånden för kraftöverföringen från Norrland att transmissionsförlusterna minskades och ASEA kom under perioden att bli ledande inom högspänningstekniken. Kraftledningen Harsprånget-Hallsberg, som öppnades 1952, innebar världsrekord i högspänning. Å andra sidan ökades också utbudet av små elmotorer, vilka vidgade möjligheterna att använda elektriciteten både inom industri och hushåll.

Inom industrin innebar perioden framför allt två saker: Enkeldriftens fullständiga seger över annan drivkraftsteknik och en geografisk spridning av modern industriproduktion. Under 1930-talet och ännu mer accentuerat efter andra världskriget ökade nyanläggningarna inom industrin. Nya företag bildades och äldre företag byggde nya anläggningar. Dessa kunde planeras från grunden efter elektricitetens möjligheter till mera ljus och rymd och en friare placering av arbetsmaskiner. Till detta bidrog naturligtvis det relativa prisfallet på elektricitet och den ökade kvaliteten och säkerheten i eldistributionen men också det nya utbudet av elmotorer. Omedelbart efter andra världskriget introducerades nämligen en ny generation elmotorer till avsevärt lägre priser än tidigare. Samtidigt infördes nya och mera specialinriktade maskiner, som ökade graden av mekanisering och därmed också kraven på en flexibel arbetsorganisation. Resultatet blev en kraftig ökning i synnerhet av den lätta industrins elförbrukning, varmed en grund lades för kommande starka produktivitetsstegringar.

Liksom under åren kring sekelskiftet samverkade åter den industriella omvandlingens ökade anläggningsverksamhet med ökad tillgång på billigare elektricitet och med innovationer på elmotorns och maskinernas område. Men i ett avseende gick utvecklingen under denna omvandlingsperiod i en annan riktning än kring sekelskiftet. Då hade koncentrationen till industristäderna ökat. Nu skapade den allmänna elektrifieringen och nya småmotorer istället förutsättningar för industriell spridning till mindre orter och till landsbygden. Småindustri och hantverk fick nytt liv genom elektrifieringens andra steg, vilket bidrog till den livliga företagsbildningen.[9]

Med hushållens ökade elanvändning skapades vidare utrymme för ytterligare ett utvecklingsblock kring elkraften - vitvaruproduktionen och hushållsarbetets mekanisering. Med bakgrund i 1920-talets utvecklingsarbete kom nu - accentuerat under 1950-talet - genombrottet för elspis, tvättmaskin och kylskåp. Revolutionen av hushållsarbetet skulle få vittgående samhällskonsekvenser. Framför allt påverkades naturligtvis arbetsfördelningen mellan män och kvinnor. Sedan början av 1800-talet hade en oförändrat stor andel av kvinnorna varit sysselsatt i hushåll, men från 1950-talet växte hastigt andelen kvinnor med arbete inom industrin eller i den likaledes expanderande tjänstesektorn.[10]

Också inom den tunga industrin ökade elförbrukningen om än måttligt. Utvecklingen av elektrostålprocessen var särskilt betydelsefull. Genom denna skapades nya förutsättningar för att konkurrenskraften skulle bibehållas inom produktionen av kvalitetsstål. Annars var den mera markanta förändringen på energianvändningens område inom tung industri en övergång från kol till olja som bränsle, vilken genomfördes hastigt i samband med de stora investeringsökningarna kring 1950.

Från slutet av 1950-talet till 1970-talets början stegrades den industriella tillväxten till rekordnivåer i Sverige liksom i omvärlden. Framför allt steg produktiviteten storartat. De nya utvecklingsblocken kring elektriciteten inom industri och hushåll, liksom kring oljan för transporter, mognade och ledde till produktionsökningar, marknadsintegration, skärpt konkurrens och allt hårdare strävan mot rationaliseringar.

Liksom under 1920-talet kom åtgärderna för effektivitetsökning tillsammans med prisfall på bränsle att hålla tillbaka industrins elförbrukning. Samtidigt inleddes en utveckling mot en ny industriell revolution. Med elektronikens och datorernas intåg övergick mekaniseringen i automatisering av hela processer. Elektriciteten som kraft mötte elektriciteten som informationsmedium. Mellan dem uppstod en komplementaritet, ett ömsesidigt beroende, av ett nytt slag. Användningen av elektronik i produktionen förutsatte en långt utvecklad förmåga att kontrollera och reglera maskiner och processer. Denna förmåga hade elektromekaniken uppnått men med elektroniken nåddes nya nivåer.

Den svenska industristrukturen gynnade ett tidigt användande och en vidareutveckling av den nya tekniken - likheterna är i det fallet stora med den tidiga elektrifieringens förutsättningar. Inslaget var stort av produktionsprocesser där styr- och övervakningsfunktioner blivit allt viktigare och där den elektrotekniska industrin låg långt framme i kunskaps- och produktutveckling. Denna skedde framför allt för behoven inom tunga områden, såsom kraftindustri och processindustri, för att därefter i mera standardiserade former nå en vidare spridning inom andra industrier.

Under 1960-talet förbereddes också en revolutionerande förändring inom elkraftsproduktionen. Redan vid mitten av 1950-talet, då den stora utbyggnaden av vattenkraften skett och då elanvändningen både inom och utom industrin växte, inriktades intresset på kärnkraften. Utvecklingen på kraftelektronikens och styr- och övervakningselektronikens områden, liksom inom materialframställningen vid stålverk och verkstadsindustri, beredde under 1960-talet vägen för kärnkraftverken. I början av 1970-talet tycktes grunden vara lagd för att Sverige skulle behålla positionen med internationellt sett billig elektricitet och för att svensk elektroteknisk industri och kraftindustri skulle behålla en position i täten för krafttekniken.

Kris, omvandling och elektrifiering från 1970-talet

Oljeprishöjningen 1973 vände konjunkturutvecklingen på världsmarknaden och utlöste en strukturkris som satte punkt för efterkrigstidens långa tillväxtperiod. Till skillnad från tidigare strukturkriser tillhörde nu Sverige de industrinationer som drabbades hårdast. Vid tidigare kriser hade starka förnyelsekrafter - med elektrifieringen som framträdande inslag - stått beredda att ta över ledningen för den industriella utvecklingen och tidigt fått stort utrymme. Nu kom istället krisbranscher och hinder mot förnyelse i förgrunden. Detta gällde också på energins område.

Trots elektricitetens stora betydelse för svensk industri hade tillväxten under 1960-talet i allt större utsträckning knutits till oljans roll i världsekonomin. Den svenska industrin hade ökat både sitt direkta och indirekta beroende av oljan. Varvs- och stålindustrin ger de tydligaste exemplen. Med en allt snävare inriktning på oljetonnage hade varven tillhört 1960-talets mest expansiva branscher. Samtidigt satsade stålindustrin alltmer på ordinär bränslebaserad produktion av fartygsplåt. Med oljeprischocken gick botten ur denna marknad och varven omkull. Stålindustrin drabbades av både höjt bränslepris och tappad efterfrågan.

Vid tidigare strukturkriser hade elektrifiering och industriell förnyelse - knuten både till elektroteknik och elanvändning - tidigt erbjudit nya tillväxtriktningar. Nu låg en sådan expansion redan beslutad med det svenska programmet för kärnkraften under 1970-talet. Men i krisen blev också kärnkraftens framtid allt mer oviss. Den verkligt paradoxala situationen uppstod därför under 1980-talet, då eltillgången ökade radikalt genom redan genomförd kärnkraftsutbyggnad samtidigt som eltillgångens framtida villkor blev alltmer osäkra.

Trots osäkerheten ökade industrins specifika elförbrukning betydligt från mitten av 1970-talet. Elektricitetens andel av total energianvändning ökade samtidigt språngartat, då den specifika bränsleförbrukningen drastiskt reducerades. Den ökade elanvändningen kan emellertid endast till en liten del förklaras av substitution till följd av de förändrade relativpriserna på elektricitet och bränsle. Elanvändningen har återigen i första hand varit knuten till en förnyelse av både metoder och produkter, som ökat värdet av elektricitetens kvaliteter. Genom utvecklingen av arbetsorganisation och arbetsmiljö, av produktionsprocesser och produkter har behoven av reglerbarhet, kvalitet och flexibilitet i energianvändningen ökat, vilket gjort elektriciteten komplementär till förnyelsen.

Med elektronikens införande skapades under 1970- och 1980-talen ett avsevärt vidgat utrymme för maskinanvändning och processtyrning. Liksom kring sekelskiftet och under åren efter andra världskriget sammanföll nu prisfall på maskiner av ökad användbarhet med sjunkande relativpris på elektricitet. Därtill fanns en stark teknisk komplementaritet mellan den nya generationen av maskiner och elektriciteten samtidigt som mekaniseringen och automatiseringen givetvis förstärktes av den ökade lönekostnadsnivån. En längre gående produktförädling och ökade kvalitetskrav både på konsumtionsvaror och kapitalvaror bidrog också till större krav på kontroll och flexibilitet i produktionsprocessen. Samtidigt som kraven skärptes på arbetsmiljön, skapades även förutsättningar för mera genomgripande förändringar av den traditionella arbetsorganisation, vilken uppkommit genom sekelskiftets motorisering och den följande rationaliseringen med enkeldriftens införande.

Framför allt har elförbrukningen ökat kraftigt inom den energilätta industrin. Dessa tillverkningsgrenar, som binder mindre fast kapital med kortare livslängd, kan snabbare reagera på nya möjligheter och har dessutom varit mindre påverkade av osäkerheten kring den långsiktiga eltillgången. För den tunga industrin var förutsättningarna annorlunda. Inom denna grupp fanns några av de branscher, som drabbades hårdast av strukturkrisen - t ex gruvor, stålverk och massabruk. De var mer känsliga för den negativa sidan av strukturkrisen med vikande investeringar och skärpt internationell konkurrens. Samtidigt påverkades de i högre grad av den framtida osäkerheten på energimarknaden. Inom den tunga industrin genomfördes emellertid en omfattande omstrukturering - i synnerhet av den krisdrabbade delen - som sammantaget innebar en kraftig reduktion i bränsleförbrukningen, en måttlig ökning i elförbrukningen samt en förändrad produktinriktning.

Gemensamt för de s k basnäringarna i svensk industri, dvs de branscher som grundats på svenska tillgångar av råvaror och energi, var att fördelarna av dessa tillgångar drastiskt minskades genom utvecklingen under 1960- och 1970-talen. Det har förekommit tidigare i historien - i synnerhet järnhanteringen har återkommande fått möta sådana situationer. Då har en vidareutveckling av processer och produkter baserad på kunskap blivit nödvändig. Men det har knappast skett så massivt tidigare som nu blev fallet. Det har tidigare inte heller skett under perioder av högt svenskt lönekostnadsläge. Mer än tidigare blev det nödvändigt med en utveckling mot effektivare användning av alla produktionsinsatser. Basnäringarna har också sedan slutet av 1970-talet genomgått omvälvande förändringar, där råvarutillgången fått mindre betydelse medan betydelsen för kunskapskapitalet ökat. I denna omvandling har elektriciteten spelat en ledande roll som energibärare. Framför allt har elektricitetens olika kvaliteter utnyttjats inom process- och produktutvecklingen för stål, massa och papperstillverkningen för att spara arbetskraft, råvaror och bränslen.

Effektivitetsökningen har snarast varit förvånansvärt stor med tanke på att förnyelse brukar vara tidsödande. Förklaringen kan vara att krisen tvingade fram nya kombinationer av existerande kunskap och att denna fanns att tillgå i tillräcklig mängd - tillräcklig för att klara en omstrukturering, vilken samtidigt gick i rationaliseringens tecken.

Två nya utvecklingsblock med eltillgång och elektroteknik i centrum kan alltså skönjas inom svensk industri under 1980-talet. Det ena finns inom processindustrierna i en omstrukturering mot ökad kunskapsorientering. Det andra finns i den vidgade användningen av elektricitet och elektronik för ny arbetsorganisation, produktinriktning och industriell miljö. Frågan är vilken roll dessa utvecklingsblock kommer att spela i framtiden.

Perspektiv framåt

Mycket talar för att världsekonomin är inne i en period av omfattande omvandling. Tidigare erfarenheter av strukturell förändring - som bl a speglats av el- och bränsleanvändningen - talar för detta. Omvandling ger nya möjligheter och nya perspektiv, men den inbegriper också hinder och konflikter. Sätten att möta dessa kommer i högsta grad att påverka utvecklingen. I grunden finns dock starka långsiktiga expansionskrafter - en förestående expansion kan bli väl så stark som efterkrigstidens rekordartade tillväxt.

I detta perspektiv väger tre faktorer tungt: Den transport- och informationsrevolution som tog fart under 1960- och 1970-talen, de stora olikheterna i ekonomiska och sociala villkor mellan regioner, länder och kontinenter och, slutligen, knappheten på naturresurser. Dessa faktorer kan påverka alla områden - institutionellt, tekniskt, kunskapsmässigt.

Moderniseringen av de tidigare planekonomierna i östra och centrala Europa kan mycket väl bli startmotor till en mera expansiv omvandlingsfas - något som i hög grad skulle påverka den svenska industrins utveckling. Men också utanför Europa finns starka expansionskrafter och investeringsbehov. I en sådan omvandling kan behovet av råvaror, energi och energitunga produkter växa språngartat. Med den resursknapphet som omger industriutvecklingen, kommer då priset att stiga. Prisstegringen kan stimulera till ytterligare kapacitetsökning inom primärproduktion, transporter och processindustri. Samtidigt kommer ansträngningarna att utveckla resurssnåla tekniker och produkter att öka. Men förnyelse tar tid och kräver investeringar. Kapacitetsbehoven ökar då ytterligare och investeringsuppgången kan förstärkas till dess att en ny strukturell stabilitet uppnås på grundval av de institutionella arrangemang som skapas under 1990-talet.

Vilken roll kan då utvecklingsblocken kring elektriciteten spela för svensk industri i detta perspektiv? Det är en fråga som rör både energitung och energilätt industri.

Den omvandling och omstrukturering av svensk processindustri, som inleddes under slutet av 1970-talet, ger en grund att växa på. En inriktning mot resurssnål teknik och produktutformning inom de områden, där behoven kan växa kraftigt, blir då en tillgång globalt liksom för svensk ekonomi. Därmed kommer strategiska insatsvaror som kunskap och elektricitet att kunna spela en framträdande roll. Avgörande är emellertid inte att billig elektricitet skulle ge konkurrensfördelar, utan att en säker eltillgång kan ge underlag för investeringar i produktion och kunskap. Detta är särskilt tydligt i perspektivet av en förestående integration av det europeiska elnätet. Då minskar differenser i elpriserna, medan betydelsen av interaktionen mellan processindustrin och den elektrotekniska industrin ökar.

Det andra utvecklingsblocket med vidgad användning av elektricitet och elektronik omfattar hela industrin med den elektrotekniska i centrum. Den svenska industrins långt framskridna elanvändning och den svenska elektrotekniska traditionen ger strategiska utgångspunkter inför en mera omfattande omvandling i denna riktning inom andra industriländer. Då skulle en påbörjad förnyelse inom svensk industri, baserad på eltillgång och eltradition, kunna skapa förutsättningar för en följande framgångsrik internationell specialisering - ett förlopp som varit en röd tråd i den svenska industriutvecklingens mönster.

NOTER

[1] Denna artikel bygger på en undersökning av elektricitetens betydelse för svensk industriell utveckling vilken finansierats av Vattenfall. En mera fullständig redovisning av undersökningen och referenser till material och litteratur ges i Lennart Schön 1990: *Elektricitetens betydelse för svensk industriell utveckling*. Vattenfall U(S) 1990/60.

[2] Om begreppet utvecklingsblock, se Erik Dahmén 1950: *Svensk industriell företagarverksamhet. Kausalanalys av den industriella utvecklingen 1919-1939*. Band I. IUI Stockholm.

[3] Förloppet kris-omvandling-rationalisering presenteras i Olle Krantz och Lennart Schön 1983: "Den svenska krisen i långsiktigt perspektiv" ur *Ekonomisk Debatt* nr 7 1983. Vidareutveckling av denna modell, bl a mot bakgrund av elstudien, görs i Lennart Schön 1991: "Development blocks and transformation pressure in a macro-economic perspective - a model of long-term cyclical change" ur *Skandinaviska Enskilda Banken Quarterly Review* nr 3-4 1991 samt i Lennart Schön 1993: "40-årskriser, 20-årskriser och dagens ekonomiska politik" ur *Ekonomisk Debatt* nr 1 1993.

[4] Walt W Rostow 1978: *The World Economy. History and Prospect*. Austin, Texas. Motsvarande trendperioder i svensk prishistoria sedan slutet av 1800-talet presenteras i Jonas Ljungberg 1990: *Priser och marknadskrafter i Sverige 1885-1969. En prishistorisk studie*. Ekonomisk-historiska institutionen Lunds universitet.

[5] Sambanden med finansiella marknader och statsskuldspolitik behandlas i Lennart Schön 1989: *From war economy to state debt policy*. Riksgäldskontoret Stockholm.

[6] Referenser till litteraturen om elektrifieringen ges i Lennart Schön 1990 a.a. Betydelsen av två mera omfattande arbeten bör dock framhållas, nämligen Filip Hjulström 1940: *Sveriges elektrifiering. En ekonomisk-geografisk studie över den elektriska energiförsörjningens utveckling*. Geographica nr 8, Kulturgeografiska institutionen Uppsala universitet, samt Jan Glete 1983: *Asea under hundra år. En studie i ett storföretags organisatoriska, tekniska och ekonomiska utveckling*. ASEA, Västerås.

[7] Prisuppgifter är hämtade ur Jonas Ljungberg a.a.

[8] Uppgifter om det tekniska utvecklingsarbetet bygger särskilt på Jan Glete a.a. - för mellankrigstiden också på Erik Dahmén a.a.

[9] Om företagsbildningen, se Dahmén a.a.

[10] Bygger på beräkningar av kvinnors oavlönade arbete i Olle Krantz 1987: *Historiska nationalräkenskaper för Sverige: Husligt arbete*. Ekonomisk-historiska institutionen Lunds universitet.

Recensioner

Munkar och järn

Anna Götlind, **Technology and Religion in Medieval Sweden**. Avhandlingar från Historiska institutionen i Göteborg 4. Göteborg 1993. 262 sid. med 46 ill. ISBN 91-0853-2, ISSN 1100- 6781.

Den 15 maj 1993 disputerade Anna Götlind på en avhandling om teknikutveckling i det medeltida Sverige. Enligt titeln handlar det om ”technology and religion”, men man skall inte förledas att tro, att det är fråga om någon teologisk avhandling. Det är teknologiska problem, som helt entydigt står i centrum för författarens intresse. Religionen, den katolska kyrkan, är här reducerad till den miljö, i vilken teknikutvecklingen äger rum. Det rör sig om en så kallad sammanläggningsavhandling och den består förutom inledning och sammanfattning av fem stycken tidigare publicerade artiklar, till vilka fogats en nyskriven. Det är knappast obekant, att denna avhandlingstyp, som introducerades i samband med 1969 års universitetsreform, haft att kämpa mot en rad akademiska fördomar och att den betraktats med stor misstro. Endast ett mindre antal doktorander har benyttjat sig av möjligheten att disputera på ett antal avslutade undersökningar. Huvudparten har istället valt en traditionellt monografisk uppläggning. Vi skall heller inte blunda för att det förekommit, att tillfälliga hoprafs av alltför disparata alster tvingats in mellan avhandlingspärmarna, vilket naturligtvis befäst farhågorna.

På denna punkt borde Anna Götlinds väl sammanhållna problempresentation kunna ge de akademiska traditionalisterna en nyttig tankeställare. Om jag förstått saken rätt, har hon redan från början av sin forskarutbildning ytterst målmedvetet valt att strukturera sitt material på ovan antydda sätt och det är tveklöst en utomordentligt effektiv metod. När den färdiga avhandlingen spikades, var Anna Götlind en välkänd och uppskattad forskare för hela det medeltida vetenskapskollektivet. Hennes teser var granskade, hon hade haft tid att bearbeta den kritik som framförts och hon hade hunnit växa in i sin viktiga uppgift. Hennes avhandling är en fjäder i hatten för vår moderna forskarutbildning och en nagel i ögat på dem som menar att allting var bättre förr.

Därmed inte antytt, att det är universitetssystemet, som skall ta till sig äran. Anna Götlind är en saklig och mycket klok person, som utan yttre åthävor och abstrakt retorik redovisar sina resultat. Hos henne finns ingenting av metodfixering och annan akademisk kosmetika, med vars hjälp mindre lyckligt lottade forskare söker spackla över sina intellektuella handikapp. Språket är enkelt och klart, den löpande framställningen välstrukturerad och frukterna av den nedlagda forskningsmödan presenteras på ett naturligt och opretentiöst sätt. Det är kort sagt en tilltalande, nyttig och, så långt vi idag förmår överblicka, tillförlitlig bok, vilket naturligtvis inte betyder, att allting är invändningsfritt. Våra faktiska kunskaper om svensk medeltid är bräckliga och ger fortfarande stort utrymme för motstridiga tolkningar.

Cistercienserordens betydelse för medeltida teknikutveckling har ute i Europa under senare decennier tilldragit sig ett mycket stort intresse. Kyrko- och konsthistoriker har sedan länge alltför ensidigt betonat ordens isolationistiska tendenser. Det är välbekant att cistercienserna ofta sökte sig till avlägsna, glest befolkade områden, vilket uppfattats som utslag av natursvärmeri – en grön våg redan under tidigt 1100-tal. Senare tiders kontinentala teknikhistoriker har emellertid mycket klart visat att cistercienserbröderna ägnade sig åt annat än kontemplation inför naturens skönhet. De var driftiga jordbrukare, vin- och fruktodlare, boskapsuppfödare och deras betydelse för Frankrikes och Englands järnhantering kan knappast överskattas. De första klostren var anlagda som självbärande enheter, som enligt ordensreglerna skulle klara hela sin försörjning utan kontakt med världen utanför de egna murarna. Detta stränga självförsörjningskrav mildrades mycket snart och redan under 1100-talets andra hälft framstod flera kloster som starkt specialiserade produktionsenheter för vin, spannmål, kött, fisk, salt eller järn.

Förhållandena i Skandinavien är inte lika väl kända och nordiska forskare har knappast ägnat cistercienserna någon uppmärksamhet, vilket är speciellt uppseendeväckande när det gäller deras järnhantering, som ute i Europa tilldragit sig ett enormt intresse. Alla torde vara medvetna om den betydelse järnet haft för svensk ekonomi, men våra forskare har koncentrerat uppmärksamheten till Bergslagens och södra Norrlands småskaligt lågteknologiska framställningsplatser, medan det cisterciensiska nyckelkomplexet i Nydala ännu ligger helt obearbetat. Det är därför utomordentligt tillfredsställande, att Anna Götlind i en bred översikt över cisterciensisk teknologi i det medeltida Sverige tangerar klostret i Nydala och de möjligheter, som det erbjuder. Här skulle man önska, att författaren haft möjlighet att ta ytterligare några steg, men så länge alla de framställningsplatser, som finns antydda i

Nydalabreven, ännu inte blivit föremål för arkeologiska undersökningar, är detta dessvärre omöjligt.

Avhandlingens tyngdpunkt ligger på järnhantering. Två artiklar behandlar den framställning och handel med järnprodukter som initierades utifrån Vadstena kloster och i en tredje artikel, "Images of Technology in the Relevations of St. Birgitta", som utreder det teknikrelaterade bildspråk vårt enda riktigt auktoriserade helgon ibland kunde använda sig av, aktualiseras en gammal tvistefråga. I fjärde bokens sjunde kapitel beskriver Birgitta livfullt och målande Yttersta domen och de fasor, som väntar den del av mänskligheten som avvikit från den smala stigen. Helvetet skildras på ett sådant sätt, att svenska bergshistoriker förutsatt att Birgitta själv stått inför en masugn, och de har uppfattat hennes suggestiva vision som ett sakligt objektivt verklighetsreportage från just en masugn. I sak är detta möjligt. Birgitta stod i nära kontakt med cistercienserklostret i Alvastra, som liksom Nydala utgått från Clairvaux, Europas ledande järnproducent, och allt tyder på att det är dessa båda kloster som introducerat masugnen i vårt land. Å andra sidan avviker Birgittas helvetesbeskrivning inte från den traditionellt kristna uppfattningen och den skall snarare ses som en rent litterär schablon. Anna Götlind varnar därför på goda grunder för att dra alltför okritiska slutsatser på basis av Birgittas visioner.

Bokens avslutande artikel behandlar teknik- och arbetsbilder i våra medeltida kalkmålningar. Den är den längsta, mest välillustrerade och ur allmän kulturhistorisk synvinkel den mest intressanta delen i detta teknikkomplex och den är inte tidigare publicerad. Syfte och metod är liksom undersökningens geografiska avgränsning klart definierade. Anna Götlind har valt att behandla Sverige med landets nuvarande gränser, vilket är det enda rimliga och en internationellt accepterad metodik, som t. ex. våra stora inventeringsverk "Sveriges kyrkor" och "Sveriges runinskrifter" ansluter till, medan det bland andra, mer provinsialchauvinistiska skandinaver blivit en vogue att i undersökningar av detta slag också inkorporera de delar av grannländerna, som under fornstora dagar tillhört fosterlandet, vilket leder till en rad helt meningslösa skenproblem: vart skall t ex Gotland föras – under en period hit, under en annan dit? Här är det bara att hoppas, att Anna Götlinds nyktra pragmatism manar till efterföljd.

Kalkmålningarnas redskaps- och arbetsbilder har tidigare ofta brukats och missbrukats i liknande studier och här finns det två skolor, som strävar i olika riktning. Konsthistoriker är ofta starkt förlagefixerade och menar att de medeltida bildkonstnärerna var helt handlingsförlamade om de inte hade tillgång till illuminerade manuskript eller träsnitt, som de i sin totala osjälvständighet kunde plagiera. Dessa förmodade förlagor anses i vissa fall vara mycket gamla, vilket betyder, att de beskriver en sedan länge övergiven teknik i en helt annan del av Europa. Bland etnologer å andra sidan finns en tydlig tendens att uppfatta samma medeltida konstnärer som vetgirigt skarpögda dokumentalister, som med fotografisk detaljskärpa gör förstudier till de vapen, klädedräkter, verktyg, byggarbetsplatser etc, som råkar finnas i det omedelbara grannskapet, studier de senare använder sig av, när de fyller sockenkyrkans valv och väggar med sina emblematiskt förenklade framställningar. På detta område har ingen förutsättningslös forskning bedrivits. Två ortodoxa riktningar har styvsint hållit fast vid sina väl inlärda dogmer och har aldrig förmåtts att pröva motsidans argument. Anna Götlind undgår naturligtvis inte att tangera dessa problem, men här saknas ännu mycken forskning, en fördjupning och en objektiv studie av en helt obunden forskare, en forskare som ännu inte valt sida. Anna Götlind har i föreliggande avhandling genom sin lågmälda försiktighet och intellektuella kapacitet dokumenterat sina möjligheter att genomföra denna för en förutsättningslös forskning nödvändiga sanering. Här återstår endast att hoppas att den kommer i en följande artikel – eller ännu hellre i en brett upplagd monografi.

Lennart Karlsson

Det japanska undret i ny belysning

Yukiko Fukasaku, **Technology and Industrial Development in Pre-War Japan: Mitsubishi Nagasaki Shipyard 1884-1934**, Routledge, London 1992, 189 sidor.

Japans framgångar på världsmarknaden och dess utveckling till en ledande industrination under efterkrigstiden är ett ämne som tilldrar sig stort intresse i västvärlden. Försök att förklara det "japanska undret" sträcker sig från diskussioner om kulturella särdrag och betydelsen av confusianism till frågan om japansk forskning är mera produktorienterad. Intrycket av denna debatt är att hela utvecklingen är ett efterkrigsfenomen. En något annorlunda bild ges i Yukiko Fukasakus bok om Mitsubishi Nagasaki Shipyard, vilken bygger på hennes doktorsavhandling från 1988. Budskapet som ges är att trenden för en kraftig japansk ekonomisk tillväxt var väl på redan före andra världskriget. Japan hade under århundraden varit avstängt från omvärlden när den amerikanske kommendören Perry med kanonbåtsdiplomati öppnade upp landet för handel med väst 1853. Trots isoleringen var japanerna väl medvetna om europernas kolonsationssträvanden. En snabb industrialisering av Japan ansågs vara enda sättet att undgå att exploateras av västvärlden. Staten tog initiativ att bygga fyrar, järnvägar, telegrafnät samt att modernisera gruvor och traditionell industri. Omvandlingen från ett jordbruks- till ett industriland tog fart på 1880-talet. Segern över Ryssland i det rysk-japanska kriget 1904-05 var bara ett tecken på att en ny industriell stormakt höll på att växa fram. Första världskrigets avspärrningar stimulerade den inhemska tunga industrin. Kännetecknande för 1920-talet var stagnation men industrin genomförde rationaliseringar för att öka produktiviteten. Efter att landet tagit sig ur krisen i början av 1930-talet och fram till andra världskriget, var den militära upprustningen helt dominerande i den japanska ekonomin.

Yukiko Fukasaku använder Mitsubishi Nagasaki Shipyard som en fallstudie för att visa hur teknik importerades och hur den ackumulerade kunskapen resulterade i små stegvisa förbättringar av tekniken, något som hon kallar "improvement engineering". Stor betydelse tillmäter hon uppkomsten av företagets forskningsorganisation. Skeppsbyggnadsindustrin var bland de första tunga industrierna att etableras i Japan och Mitsubishi var ett av branschens största företag. Genom att studera Mitsubishi menar hon att en allmän förståelse för tekniköverföringsprocessen i andra industrier kan erhållas - att mönstret från varvsindustrin går igen i branscher som utvecklades i ett senare skede av Japans industrialisering. Det centrala budskapet är att förklaringen till Japans framgångar efter andra världskriget kan sökas i förkrigstiden. Även om industrin vid krigsslutet låg i ruiner rent materiellt sett så överlevde organisationerna och kunskapen. Det materiella kapitalet var betydlig enklare att bygga upp än det kapital som representerades av kunskap och erfarenhet hos de anställda.

Under Japans isolering (fram till 1853) var det förbjudet att tillverka stora oceangående fartyg. Det fanns dock en tradition av att bygga mindre segeldrivna träbåtar för kustfart. Då en "modern" varvsindustri skulle byggas upp under 1800-talets andra hälft ansågs det angeläget att snabbt inhämta kunskap från västvärlden. De första kontakterna togs med ryssar och holländare under 1850-talet. Under 1860-talet var fransmän verksamma vid byggandet av varvsanläggningar, men därefter var det framförallt britter som anställdes vid varven. Utöver att anställa utlänningar kunde teknikimport ske genom att skicka japaner på studieresor till Europa och USA. Den betydelse som regeringen tillmätte detta framgår t.ex. av att 4,3 % av statsbudgeten under åren 1868-1877 gick till resor. Även tekniska tidskrifter ansågs vara viktiga bärare av kunskap.

Ett stort problem för japanska varv långt in på 1900-talet var bristen på inhemska underleverantörer. Såväl maskiner som fartygsplåt måste importeras, främst från Storbritannien som vid denna tid var världens dominerande skeppsbyggarnation. Detta fick till följd att japansktillverkade fartyg var dyrare än brittiska ända fram till början av 1930-talet trots att lönerna var lägre i Japan.

Av största betydelse för Japans begynnande varvsindustri var att ha tillgång till utbildad arbetskraft. Som nämnts anställdes till att börja med utlänningar för att leda arbetet på varven. Såväl ingenjörer som yrkesskickliga arbetare importerades. De förväntades naturligvis att lära upp japanska arbetare, men alla västerlänningar var inte lika villiga att dela med sig av sin kunskap. Under 1800-talets sista decennier minskade antalet anställda utlänningar. Ett skäl till detta kan ha varit en önskan om att minska beroendet av utlänningar. Det huvudsakliga skälet var dock att allt fler universitetsutbildade japaner fanns att tillgå och dessa var billigare att anställa. Vid Tokyo universitet, där det sedan 1877 funnits ingenjörsutbildningar inom väg- och vattenbyggnad, maskin-, kemi- och gruvteknik, startades 1884 en avdelning för skeppsbyggnad. De universitetsutbildade skeppsbyggnadsingenjörerna fick ofta höga positioner vid varven direkt efter examen. Utbildning av arbetare och förmän ägde främst rum inom företagen.

Regeringen tog under 1900-talets första decennier aktiv del i skapandet av olika forskningsinstitutioner. Man uppmuntrade också till forskning vid universiteten. Flottan bedrev från tiden för rysk-japanska kriget egen forskning inom en rad områden såsom trådlös kommunikation, elkraft, optik, flygteknik m.m. Mitsubishi satte 1904 upp ett företagslaboratorium för att utveckla nya stålkvalitéer. Verksamheten utvidgades snart till andra områden. År 1908 byggdes en experimenttank där fartygs motstånd kunde beräknas genom släpförsök med modeller. Forskningslaboratoriet var betydelsefullt då importerad teknik förbättrades. Försök att generera ny teknik var dock mindre lyckade. Under 1930-talet stärktes forskningssammarbetet mellan militären, företaget och universiteten i takt med upprustningen. Det fanns således redan före andra världskriget en medveten policy rörande forskningen, vilken syftade till "improvement engineering".

För att exemplifiera hur tekniköverföring ägt rum och hur små stegvisa förbättringar på importerad teknik införts behandlas i boken tre teknologier vilka haft stor betydelse för skeppsbyggeriet under 1900-talet: ångturbinen, dieselmotorn och den elektriska svetsningen. De två förstnämnda var förändringar i själva produkten. Elektrisk svetsning å andra sidan hade sitt största värde i att förenkla produktionsprocessen.

Mitsubishi köpte 1914 licens på den metod för elektrisk svetsning med täckta elektroder som Oscar Kjellberg utvecklat under 1900-talets första decennium. Personal sändes till Sverige för att under tre månader genomgå ett träningsprogram hos Elektriska Svetsningsaktiebolaget (ESAB). Efter återkomsten till Japan startades egen tillverkning av elektroder. Elektrisk svetsning användes i början uteslutande vid reparationsarbeten men med tiden utvidgades användningen till att även inkludera vissa detaljer vid nybyggnation. I Mitsubishis forskningslaboratorium vidareutvecklades den kjellbergska metoden, bl.a. med målet att kunna svetsa i olika metaller samt i gjutjärn.

Det första världskriget innebar ett ökat behov av fartyg. Dels berodde detta på att fartyg sänktes, dels på det ökade transportbehov som kriget medförde. I USA uppfördes enorma varvsanläggningar. Hog-Island-varvet utanför Philadelphia hade 50 stapelbäddar där fartyg monterades samman av förfabricerade sektioner. Nitning var det naturliga sättet att sammanfoga materialet men tankar om att kunna öka produktionen genom att använda elektrisk svetsning låg i luften. Även om de inte kom att realiseras förrän långt senare fick de ändå till följd att experiment med mindre helsvetsade fartyg kom att utföras i flera länder. I England sjösattes 1920 ett mindre kustfartyg, M/S "Fullagar" vilket ofta refererats till som världens första helsvetsade fartyg. Samma år tillverkade ESAB den helsvetsade båten "ESAB IV" vilken kom att fungera som flytande svetsverkstad i Göteborgs hamn. ESAB:s franska dotterbolag hade redan 1919 byggt en liknande båt. Mitsubishi sjösatte 1920 den helsvetsade färjan "Suwa", vilken var något större än M/S "Fullagar". Det skall dock betonas att samtliga dessa byggen var av experimentkarraktär och att de inte fick några omedelbara efterföljare.

Nedrustningskonferensen i Washington 1922 satte upp begränsningar för världens örlogsflottor, vilket stimulerade användandet av svetsning eftersom en reduktion av vikten innebar ökad stridskapacitet för ett given fartygsstorlek. Elektrisk svetsning kom under 1920- och 1930-talen att användas i allt fler applikationer ombord och mot slutet av 1930-talet byggdes stora handelsfartyg helsvetsade. Utvecklingen i Japan var parallell med motsvarande utveckling i t.ex. USA och Sverige. Massproduktionen av standardiserade s.k. "Libertyfartyg" i USA under andra världskriget var det stora genombrottet för svetsningen, men det var bara fortsättning på en utveckling som varit på väg i flera decennier.

I diskussioner om tekniköverföring betonas ofta värdet av individen som bärare av kunskap. Som nämnts ovan dominerades kunskapsimporten till Japan först av utlänningar som anställdes för att lära upp japaner och sedan allt mer av japaner som for på studieresor till Europa och USA. Särskilt viktigt var köpen av licenser. Ett fall som avviker något från detta mönster återges i boken. Betydelsefullt för USA:s fartygsbyggnadsprogram under andra världskriget var att man hade utvecklat automatiska svetsmaskiner. Dessa drev upp hastigheten i produktionen. Japanerna kunde naturligtvis inte få tillgång till tekniken på grund av kriget. Mitsubishis forskningsingenjörer byggde en fungerande kopia av den amerikanska Unionmelt-maskinen efter att ha sett ett foto av den i en annons i *Welding Journal*. Här är alltså ett fall av tekniköverföring under krigsförhållanden då de vanliga kanalerna var avstängda. En förutsättning för att lyckas var naturligtvis den kunskap om svetsning som successivt byggts upp under de föregående decenniernas forskning. Denna typ av immateriellt kapital överlevde den materiella förstörelsen under krigets sista år och bidrog till Japans framgångar under efterkrigstiden.

Att boken saknar illustrationer är beklagligt då dessa skulle berikat framställningen. Frågan om huruvida en fallstudie av ett företag kan ge allmänna kunskaper om tekniköverföring till Japan kan diskuteras. Att Mitsubishi var branschledande och att varvsindustrin var en av de tidigaste industrierna att utvecklas talar dock för detta. Yukiko har med sin välskrivna bok bidragit till en ökad förståelse för Japans utveckling till en ledande industrination under 1900-talet. Det är dessutom mycket glädjande att överhuvudtaget kunna hitta en japansk teknikhistorisk bok översatt till engelska - må det komma fler sådana i framtiden.

Lars Olsson

När ångtekniken kom

Helge Kragh (red), **I røg og damp: Dampmaskinens indførelse i Danmark 1760-1840.** Teknisk Forlag A/S, Köpenhamn 1992. 111 sidor.

Ett seminarium anordnat av TISK-projektet i Roskilde uppmärksammade 1990 att tvåhundra år förflutit sedan den första ångmaskinen togs i bruk i Danmark. Man noterade här bl.a. att förhistorien till denna händelse var mycket dåligt känd och dokumenterad trots tillgång på ett rikligt källmaterial. Fem danska teknikhistoriker antog denna utmaning och presenterar här var sin studie av en viktig period i dansk historia, uppspelet till den industriella revolutionen.

Newcomens ångmaskin tillkom för att driva gruvpumpar. Tekniken spreds efter hand från England till gruvföretag på kontinenten. Denna tekniköverföring från i-land till u-land stötte ofta på stora svårigheter. I sin doktorsavhandling *Technology on Trial* (Uppsala, 1984) analyserade Svante Lindqvist de olika problem som drabbade det första svenska ångmaskinsprojektet, Mårten Triewalds anläggning i Dannemora 1736. Erfarenheterna av detta var så nedslående att det kom att dröja ända till 1765 innan ett nytt försök gjordes i Sverige, nu vid Persbergs gruvor.

I Danmark hade man naturligt nog inget behov av denna nya teknik. Det skulle därför dröja ytterligare 25 år innan den första ångmaskinen installerades där. Den var av Boulton & Watts typ och användes som kraftkälla i ankarsmedjan vid marinens varv Holmen i Köpenhamn, Danmarks största arbetsplats. Maskinen i Dannemora hade i alla sina delar byggts i Sverige, men den danska maskinen sattes ihop av delar, i hemlighet utsmugglade från England. Men här, liksom tidigare i Sverige, blev det snart problem med att hantera den nya tekniken.

Flemming Steen Nielsen skriver om de många turerna kring detta projekt, som - liksom det i Dannemora - slutade i ett fiasko. Bakom det hela stod den danska staten med sin då starkt merkantilistiska samhällssyn. Minsta möjliga import samt statlig satsning på hemlig produktion med anlitande av utländsk expertis, det var hörnstenar i tänkandet. Inte förvånande att det snart kom till en personlig konflikt mellan "projektledaren" overkrigssekretær Rosenkrantz, djupt förankrad i merkantilismen, och Holmens dynamiske verkstadschef Henrik Gerner.

När sedan Gerner avled 1787 och Rosenkrantz avgick året därpå, blev problemen än större. Man lyckades dock få maskinen att fungera en tid, men den måste ofta repareras och den slukade kol i så stor mängd att man till slut insåg det meningslösa i att fortsätta driften. Man gjorde ett försök med ombyggnad med dubbelverkande cylinder, men efter elva års drift var det hela slut 1802.

Likheterna med misslyckandet i Sverige är stora. Man saknade i båda fallen den teknikvana och den infrastruktur som behövdes för att plantera en importerad högteknologi i den nya miljön. En skillnad mot det svenska fallet är att danska staten med sina stora resurser nu var beställaren; här fanns inte samma ekonomiska begränsningar som i Dannemora.

Berättelsen om "Ildmaskinen på Gammelholm" är den centrala i boken. Den föregås av Helge Kraghs artikel om hur den tidiga ångtekniken utvecklades helt autonomt utan egentlig hjälp av samtida naturvetenskapliga framsteg. Sadi Carnots grundläggande arbete om värmemaskiner från 1824 förblev okänt av ångtekniker långt fram i tiden. Keld Nielsen skriver om Jens Kraft, professor i matematik och filosofi vid "Det Ridderlige Academie paa Sorøe", som i en lärobok 1763/64 beskriver Newcomens "Ildmaskine". Men då detta var långt före Carnot, fanns ingen teori för maskinens termodynamiska verkningssätt, och Kraft själv hade aldrig sett någon Newcomenmaskin. Även om boken kom att väcka intresse för denna nya teknik, fick den ingen direkt betydelse för införandet av ångtekniken i Danmark.

Frank Allan Rasmussen skildrar den fortsatta utvecklingen efter debaclet med maskinen på Holmen. Redan tio år senare togs kontakter med Boulton & Watt i Birmingham om inköp av en dubbelverkande ångmaskin för myntverket i Köpenhamn. Nu var export från England tillåten, och man behövde inte smuggla in delar till ångmaskinen.

I sista kapitlet skriver Dan Ch. Christensen om den tillverkning av ångmaskiner som kom igång i Danmark på 1820-talet. Här är intressant att läsa om hur den nygrundade Polyteknisk Læreanstalt under Ørsteds ledning kom att bli så teoriinriktad att den knappast gav något egentligt bidrag till ångteknikens utveckling under sina första 30 år. Vid det samtidigt inrättade Teknologiska Institutet i Stockholm var problemet i början det motsatta: undervisningen där var helt och hållet praktiskt inriktad och överhuvud taget mycket elementär.

Med tiden kom det att rätta till sig både i Köpenhamn och i Stockholm; praktiska och teoretiska studier i kombination blev kännetecknet på den högre ingenjörsutbildningen i Danmark och Sverige.

Boken *Skruen uden ende* (rec. i *Polhem* 9,1991,78-86) visade den starka vitaliteten i dansk teknikhistorisk forskning. I den nya skriften har det tidigare internationella perspektivet bytts ut mot ett mer nationellt, men det gör den inte mindre intressant. De danska erfarenheterna från industrialismens genombrottsår är allmängiltiga.

Jan Hult

Ett litet gjuteri vid Säveån

Ulf Stahre, **Britanniafabriken 1893-1993. Ett gjuteris historia.**
Britanniafabriks AB, Stenkullen. 105 sidor.

Sveriges första mekaniska bomullsspinneri inrättades 1796 vid Gamlebo Kullen intill Säveån i Lerums socken. Efter en brand 1846 nedlades företaget. Två kilometer uppströms därifrån, vid Stenkullen, grundades 1893 ett metallgjuteri, som i dag är det äldsta industriföretaget i Lerum.

Britannia Metall Waaren-Fabrik i Werdohl, Tyskland, grundades av Johann Friedrich Colsmann. Man tillverkade bl.a. matbestick i en legering av tenn, koppar och antimon, kallad *Britannia*. Exporten till Skandinavien hämmades av höga tullar; Colsmanns lösning blev att starta tillverkning i Sverige. Intill västra stambanan och med vattenkraft från Säveån inrättade Colsmann den nu hundraåriga Britanniafabriken. Till jubileet har sammanställts en intressant historik, rätt litet tyngd av bokslutsrapporter men med skildringar av produktionen och arbetslivet, i många fall grundade på intervjuer med äldre gjutare genomförda i samarbete med Dialekt-, ortnamns- och folkminnesarkivet i Göteborg. Många fotografier och ritningar ger denna industrihistoria ett särskilt värde.

Britanniafabriken förblev länge en isolerad industri på landet, långt bort från storstaden Göteborg. Ett slags patriarkaliskt system levde kvar; först 1937 bildades här en lokal fackförening.

Jan Hult

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