WORKING PAPER

MANAGEMENT AND TECHNOLOGY LIFE CYCLE: TWO ORIGINAL BULGARIAN TECHNOLOGIES
(Case Studies of Electrotermia and of Predima)

E. Razvigorova
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Editors

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FOREWORD

Strategic planning and coordination decisions become more and more important when opportunities for extensive economic development are limited by scarce material, energy and labor resources, by frequent and unexpected changes in the market situation, and by the increased technical and technological complexity of production processes. These decisions must fulfil the main goals of the producers, guarantee their survival, and therefore affect the basic tasks of their development: to define competitive and efficient products in the immediate and more distant future, to open sales markets, to secure sub-contracting relations with suppliers, to develop and renew production facilities, etc. this is the basis on which producers form the developmental strategy for periods of 5, 10, 15 or more years.

The creation of a developmental strategy in business organizations is preceded by analyzing and evaluating the current situation: technical level of products and technologies, economic production and sales results, marketing relations, prevailing organizational and management conditions, and personnel issues. Based on these analyses and evaluations and taking into account decisions of higher state authorities, companies define their production potential and strategic goals, and then alternative developmental strategies to reach those goals.

Apart from the numerous practical problems faced by business organizations in forming a developmental strategy, a fundamental methodological problem is selecting tools to analyze indicators and alternatives, compare technical and economic achievements, rank alternatives, select products, technologies, etc. Therefore, during recent years, much research has been aimed at creating a methodological basis of strategic planning (management) through creating, selecting and empirically testing tools which are suitable for strategic analysis and evaluation, such as: symbolic models, graphical and graphic analytical forms, matrix methods, and others.

This theoretical applied study "Management and Technology Life Cycle" presents the results from the first stage of two Bulgarian case studies, one conducted at the Electrotermia Company, one at the Predima Company. The study is being carried out in fulfillment of the research plan of the Institute for Social Management's Problem Center on the Management of Technological Development, in order to meet Bulgaria's national demand for a complex and systematic analysis of the problems of technological strategic management. The study also responds to the need to improve the management system of technological development at Bulgarian business organizations. The study's results fulfil the contractual obligations of the Institute's Problem Center and both the Electrotermia Company and the Predima Company with the

International Institute for Applied Systems Analysis in Laxenburg, within the framework of the "Management of Technological Change" project, part of the "Technology, Economy & Society" program.

The following groups of technologies were considered in choosing the study objects:

Group A: New technologies, based on Bulgarian inventions
Group B: New technologies for traditional industries (mainly license technologies)

This paper presents the results from the first stage of the case studies on the technology for laying protective coatings on electrodes for use with electric arc furnaces in steel production and on the technology for producing worsted fancy years known as "Predima."

The two technologies investigated find themselves at different phases of the life cycle. Electrotermia is in the maturity phase, the second in the growth phase. This difference between the two technologies provides an opportunity to compare their development as well as their management systems.

The Electrotermia study was conducted by Dr. Vassil Peev and Dr. Georgi Kiosev, both from Electrotermia, and Dr. Julia Djarova and Dr. Ivailo Nenov, both from the Institute for Social Management.

The Predima study was conducted by Dr. Milko Dimitrov and Mr. Phillip Phillopov, both from Predima, and Dr. Lubomir Glushkov and Mr. Methodi Ivanov, both from the Institute for Social Management.

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Program Leader
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MANAGEMENT AND TECHNOLOGY LIFE CYCLE: A THEORETICAL APPLIED STUDY ON THE TECHNOLOGY FOR LAYING PROTECTIVE COATINGS ON ELECTRODES (The Electrotermia Case)

V. Peev, G. Kiosev, J. Djarova, and I. Nenov[1]

INTRODUCTION

In 1985, steel production (see Figure 1) reached 713.5 million tons, of which 156 million tons were produced in arc furnaces, a 4% increase as compared to 1984. The forecasts for the period 1984-1990 point to maintaining total steel production at the same level and foresee that the growth rate of electrically produced steel will continue to range between 3 and 4%.

Against a background of an overall decrease in total steel production, consistent growth of the actual production of electrical steel and its share in total production is striking. This is due to the obvious strengths of the electric arc furnaces. This technology had already appeared on the market at the beginning of the 20th century. Its productivity was very limited, the price of the product too high, and it was used only for producing high quality steel. Figure 2 shows the four main stages in the development of electric arc furnace operation, before gaining in 1985 the reputation of a universal method, equally efficient for producing normal and special steel.

The technology improved in parallel with the development of the arc furnace. Figure 3 illustrates the impact of the technology on the main production parameters of this type of furnace during the period 1965-1985. The analysis begins in 1965 because this marks the start of changing the philosophy of using electric arc furnaces.

The greater power of transformers created opportunities to improve productivity considerably, and also imposed the introduction of a number of constructive and technological changes. Some of the major changes and their influence on the three main indicators which determine the economic efficiency of the electric arc furnaces are shown in Figure 3.

An essential element in the cost structure of electrical steel is the expenditure for graphic electrodes. This makes up

[1] Dr. Vassil Peev and Dr. Georgi Kiosev are both from the Electrotermia Company, Sofia. Dr. Julia Djarova and Dr. Ivailo Nenov are both researchers at the Institute for Social Management, Sofia.

15-20% of direct production costs. Therefore, electrode consumption has always been the object of serious study, both by the electrode producers and the steel producers. As a result, since 1960, there has been a tendency to constantly reduce the consumption of graphite electrodes (see Figure 4). Among the factors which have contributed most essentially to reducing electrode consumption are constructive and technological improvements made to the arc furnaces and the introduction of automatic process control.

The Electrotermia Company has been working on optimizing the use of graphite electrodes in the electric arc furnaces and on the related technological and constructive problems.

The subject of the present study is to realize and develop the set of Bulgarian patents for protecting the graphite electrodes from side oxidation.

1. OBJECT AND METHODOLOGICAL PRINCIPLES OF THE STUDY

1.1. Subject and Object of the Study

The subject of the study is the process of creating and developing the technology for laying protective coatings on electrodes for electric steel production, its entry on the Bulgarian and international markets, and the organizational framework in which the innovation process developed.

This process includes the creation of a new product -- the protective coating for graphite electrodes, applied in practice for the first time, with a new technology and on a unique machine.

A characteristic feature of the object is the fact that the innovation process, beginning with the idea for a new technology to its commercial realization and transfer domestically and abroad, was not concentrated in one business organization. The team who created the invention first worked at the "Lenin" plant in the town of Pernik as a unit of the Research Institute on the Ferrous Industry, until an independent company was established. Foreign sales are administratively and methodologically subordinated to the "Technika"-foreign trade organization of the Ministry of Trade and the State Committee for Research and Technology. Therefore, it is not possible to study developments only in the Electrotermia Company; other organizations must be included as well.

Electrotermia was created by a decision of the Council of Ministers in 1975 to produce protected electrodes; develop, improve and produce complete installations for laying protective coatings on graphite electrodes; develop and implement direct current electric arc furnaces; and produce graphite electrodes with local raw materials.

1.2. General Methodological Principles of the Study

The study "Management and Technology Life Cycle" is directed to revealing regularities of technological development, elaborating the relation between technology dynamics and the development of management systems, and analyzing the company's developmental strategy.

The final results from the study have been obtained, passing through several stages with the following specific tasks:

STAGE ONE: Determining the state of the technology's development and its management system for a selected period; analyzing the problems related to the management of the innovation process at Electrotermia.

STAGE TWO: Identifying the future development of the technologies and the conditions to accelerate this process, with recommendations for applying suitable management strategy, organizational forms and management methods.

The following tasks have been solved during the first stage:

a) To define and analyze the technology life cycle;

b) To trace and analyze the organizational forms which have accompanied the development of the technology;

c) To draw conclusions and make recommendations about the future development of the technology and its management.

The selected technologies have been studied from their creation to their practical application and development. The dynamics of the technology and its characteristics were selected to serve as a basis for defining what is general and what is specific in the technology's development as well as for distinguishing its stages.

To facilitate the analysis and future management improvements, the hypothesis that the management system and its elements change depending on the stage of technological development was tested empirically. In connection with this, the study is structured in two fields:

1) Analysis of technology dynamics and technology assessment;

2) Analysis and evaluation of the management of the technological innovation process from creation to implementation and further development of the technology.

The analysis of technology dynamics is based on the technology life cycle and the stages in its creation and development. In order to construct the life cycle, different data are used which can be formalized. Mainly economic indicators are used to differentiate the life cycle phases. They are selected in order to correspond with the study's goals, but often the classical curve of the life cycle gives only a very general and incomplete picture of the development of a given technology. If only the life cycle concept is applied, it is not always possible to conduct the required in-depth analysis of the main features of the innovation process, even more so when the goal is to reveal the problems in the management system of the technological development process. Therefore, as a basis for analyzing the dynamics of the technology, the stages of its creation and development as well as the changes in its main characteristics over time were also used.

The final conclusions concerning the dynamics of the technology are based on the assessments about the two main dynamic characteristics -- the life cycle and the stages of technological development.

The assessment of the technology level is directed at defining its position in comparison with competitive technologies. Through comparative analysis of the main technological elements, conclusions are drawn about its present and future competitiveness. A main aspect in technology assessment is defining its significance for the business organization which creates and implements it as well as for other organizations -- consumers and the national economy. The degree and fields of its dissemination multiplication, and effect domestically and abroad indicate both the limits of the technology and its competitiveness.

The analysis and evaluation of the management of the technological process has been done in several cross-sections in accordance with the stages of its creation and development:

* Analysis of the organizational forms with regard to the subject of activities; subordination; and relations with superior, subordinate and associated units.

* Analysis of the economic conditions of the organizational units: financial and credit relations, planning technology, stimulation, etc.

The results from the second main field of study are necessary in order to define the advantages and disadvantages of the organizational forms and methods at each stage, of the organizational strategy as well, in order to draw conclusions about improving the management system under conditions of accelerated technological development.

2. TECHNOLOGY DYNAMICS

2.1. Technology Life Cycle

In order to construct the life cycle of the technology for laying protective coatings on graphite electrodes, the following indicators were used: production volume of protected electrodes produced with this technology, and the technology sales volume (i.e. sales of licenses and equipment).

Production Volume

The study covers the period 1962-1986, i.e. from the implementation of the first technology until 1986. On the basis of production data (see Figures 5 and 6), it is possible to conclude that:

* The production of protected electrodes in Bulgaria and in the world is growing constantly, and

* During the period 1983-1986, there was a tendency to slow down the growth rate of this production both in Bulgaria and abroad.

At present, the foreign production of protected electrodes using this technology is done through the sale of licenses.

The declining growth rate of coated electrode production in Bulgaria can be explained by the fact that all electric arc furnaces are using these electrodes, and growth would be possible only when new production facilities are created.

The declining growth rate of the global consumption of protected electrodes is due to the following factors:

1) During 1980-1987, as a result of the policy for technical and technological renovation of the electric arc furnaces in the world, the total consumption and relative share of electrodes declined considerably (average consumption of electrodes fell from 6.5-7 kg/ton to 3.5-4.5 kg/ton). This reduced the total consumption of electrodes in the world, affecting as well the consumption of protected ones.

2) The declining price of electrodes during the last years also influenced the dissemination of the method, as the economic effect decreases in proportion with the reduction in price. The fall in electrode prices is due to their increase produc-

tion and supply and to the reduced consumption of electrodes per ton.

2.2. Stages in the Creation of the Technology

The idea to create protective coatings appeared in 1958, in the Lenin metallurgical works. In 1962, this idea was recognized as an invention and the inventor received a certificate of authorship. A small research laboratory was set up within the company to work further on the problem.

Stages in the Development of the Protective Coating

During the period 1958-1986, several types of coatings were developed. Actually they represent the stages in the development of the coating:

* Coating of SiC and B_2O_3: This coating is highly impervious, but has a low thermo-resistance (up to 1500°C). It is also an isolator. Despite this, this was the first coating applied in small industrial furnaces (up to 4 tons) and was successfully used in the period 1960-62 in Bulgaria.

* Coating of SiC and Al: As a result of further studies trying to eliminate the weaknesses of the first coating, the SiC was later combined with Al. As a result of the changes in the structure of the alloy, the new coating became electrically conductive and its thermo-resistance improved (up to 1650°C). Irrespective of the improved technological properties, the coating was produced using a very complicated and sensitive technology. Therefore it was only applied during 1962-64 in the Lenin works. At the same time, the studies for optimizing the coating composition continued.

* Coating of Al alloy: It was not possible to eliminate the above limitations before 1968, when an Al alloy was developed, containing Si, SiC, Ti, and B, and possessing all qualities needed for a stable use of the coating in industrial conditions. At this stage, and based on a new certificate of authorship which was patented in all countries with developed electrical metallurgy, the coating spread broadly in Bulgaria and was offered on the international market.

* Coating of Al-Fe-Ni: The anti-corrosion properties of the coating were further improved as a result of intensive research during 1980-84. Consumption of electrodes was reduced 5-8%, thus raising the economic efficiency by about 60%, as compared to previous coatings.

Stages in the Development of the Machines for Laying the Protective Coating

* A model machine was created based on the Norton lathe. The electric arc processing which determines the machine's productivity is done with 300A power of electric current, and the low productivity limited its application only for producing small batches.

* In 1968, a production shop for making protected electrodes was set up to fulfil domestic needs. For this shop, a flow line or production line was designed in which each technological operation was performed on a specialized machine. The flow line increased productivity and made work easier. Such a line required considerable investment. Flow lines of this type were installed in production shops in Bulgaria and the United Kingdom.

* The problem of electric arc processing with a very strong current was solved in 1971, which allowed synchronization of all operations. The first automatic lathe in the family of machines was constructed in 1974. It proved to be of good quality and from 1975-87 has been constantly modernized without introducing essential changes in its main concept.

Improving the Management of the Technological Process

The management of the technological process was improved simultaneously with the development of the product and equipment. the study of the chemical processes developed in the process of laying the protective coatings, of the processes developed in the electric arc furnaces and in mastering a number of processes related to the control and focussing of the arc, etc. made it possible to completely automate the process.

The further study of the process made possible the introduction of automatic control using mathematical models. The forecasts show that it will be possible to install a production system with central computer control around 1990.

2.3. Efficiency of the Technology for Protective Coatings

The first generation of the technology (until 1968) was realized on machines with manual regulation of the process parameters. The percentage of manual work was comparatively high, not all of the operations were standardized and therefore the quality of the coatings varied.

The broader application of the method and its significant economic efficiency demonstrated the necessity of creating a production unit with a semi-automatic flow line for producing the protective coatings.

Some technological problems which had limited synchronizing the separate technological operations were solved during 1971-73, making it possible to create the automatic lathe.

The analysis of the period under review shows that after the method appeared, efforts were directed to improving the quality and increasing the reliability of the machines, introducing mechanization, automating the production processes, and improving the accompanying equipment.

Finally, some conclusions about the technology dynamics can be made (see Figure 7). The market penetration process follow the typical S-curve of the life cycle. The forecasts of market behavior after 1987 anticipate a sharp fall in sales.

In order to secure the necessary economic benefits based on long-term planning, new effective coatings have been developed and must be implemented shortly before the patent rights expire, in order to create a second life cycle of a new product which replaces the previous one. The growth phase is expected to be shorter than that of the previous product, and the saturation phase is expected to start around 1996.

The new protective coating was developed during the period 1982-1986, as a result of extensive research and development activities. The new coating was created on the basis of a Al-Fe-Ni alloy, and has an improved oxidation resistance and high electric conductivity. The increased oxidation resistance delays the start of graphite oxidation by 10-15 hours, resulting in a greater savings of graphite electrodes (5-7%).

The machines to apply the protective coating were also improved during this period. The main advantage of the improved equipment is the high degree of automation and productivity. The new machines fulfil all technological process requirements and all demands of the manufacturers of graphite electrode protective coatings.

* The life cycle of inventions for the organizations which have created them and derive incomes from the sale of licenses is limited to 20-25 years by the duration of the patent. This cycle, however, can be extended by constantly creating new and improved patented technologies and products.

* One way to secure economic efficiency after the patents expire is to set up joint ventures.

* It is necessary to seek new markets where Bulgarian production facilities can be used and where royalties can be included in the sale price of the product.

3. ASSESSMENT OF THE TECHNOLOGY LEVEL

3.1. Comparative Analysis with Competitive Technologies

With regard to the competitiveness of the Bulgarian method for protectively coating graphite electrodes, it is necessary to point out that this is the only industrially applied method available on a global scale. This determines the competitiveness of the protected electrodes as a product, of its production technology, and of the machine which lays the coating. These three possible objects of competition are protected with 15 patents in 18 countries. This is, however, only a legal protection. Technically, the Bulgarian technology has potential competitors from firms which conduct research on protectively coating electrodes.

The materials created during the 1950's, resistant to heat of 1700-2000°C, correspond to the conditions of the electric furnace. It has been tried many times to create a coating which would protect the electrodes from side oxidation. Technically, they can be classified as follows:

Impregnation of Graphite Electrodes

The electrodes are impregnated with phosphor and boron compounds, which protect the graphite up to 1000°C. Above this temperature, the oxides of these compounds stimulate graphite oxidation. Therefore, they cannot protect the electrodes in the furnace; rather they enhance its oxidation. This major drawback explains why impregnation has not been widely applied in practice.

Oxide Coatings

Coatings of Al_2O_3 and ZrO have been tried. These coatings are laid on through injection, but do not interact chemically with the graphite. Due to the oxide layer's high melting temperature and the small difference in the line expansion coefficients, the coatings crack and are destroyed long before coming to the furnace.

The casting of boron and silicon, carbide compounds, proposed by the Italian firm, Fosseco, use a different application method, but did not become widespread since it is usable only below 1200-1300°C and involves additional work for the service staff.

Carbide and Silicon Carbide Coatings

The main compounds in these coatings are SiC, the Si compounds of Ti and Mo, etc. Their main economic limitation is their high cost. In order to lay these coatings, the electrodes must be heated to 1500°C, which is unacceptable for steel producers.

Metal Coatings

These are melted and applied galvanically through injection, using plasma methods. The galvanic application has limited possibilities with regard to the coatings' chemical composition and is therefore not interesting. Their alloys can be applied and are heat-resistant up to 3000°C, but not for more than 2 minutes; they are therefore not interesting for steel producers.

Two types of coatings have been produced in small quantities through the injection of melted material:

* coating of Al and Si alloy and
* coating of Fe, Si, Cr, and Al alloy

Industrial experiments with the first type have been done by the West German company, Sigri (the second producer of electrodes in the world). They did not have much success on the market due to low heat-resistance.

The second type has been produced by the Japanese firm, Mitsubishi. Their coating is less heat-resistant. They have a low cohesion with the graphite and the frequent temperature changes in the furnace. The large difference in the expansion coefficients make for a weak connection between the electrode and the coating, which then cracks and falls off.

Combined Electrodes

This is a fundamentally different construction, consisting of an upper metal water-cooled electrode with two graphite electrodes under it. It was developed by several well-known firms: Kof, ATS, and Krupp (Federal Republic of Germany), Stelko (Canada), and British Steel (United Kingdom), etc.

During the period 1985-86, the combined electrodes were topical, but were not commercialized due to the problems they create in the normal functioning of the furnace.

It is difficult to compare the Bulgarian protective coating with its competitors, using economic and sales indicators, because most of the above cited methods for coating electrodes have not been implemented as industrial production methods. Therefore, a comparative analysis was made using some of the technical and economic indicators in implementing Electrotermia's protective coating and of the combined electrodes produced by the firms ATS and Stelko (see also Figure 8).

COMPANY	REDUCTION OF ELECTRODE CONSUMPTION (%)	NET ECONOMY ($/ TON STEEL PROD.
ATS	20-30	0.41-1.70
Stelko	20-25	2.00-2.86
Electrotermia	20-25	1.09-2.10

Judging from the data on the consumption of electrodes per ton of steel, one can say that the first two systems have been tried in production, but are no longer used.

The main factors why these technologies (i.e. those using a water-cooled metal electrode and those which consume a graphite electrode) are no longer used can be summarized as follows: higher capital investments, lower technical reliability, more complete operations to set up the electrode columns.

The analysis of the water-cooled electrodes, done at the European Congress of Electric Arc Furnaces (Florence, 1986) shows that this method of saving graphite turned out to be technically inadequate and was rejected by steel producers.

The Electrotermia method requires little investment, and the manipulation of the electrodes is the same as that of non-protected ones.

The general conclusions drawn from analyzing the competitive position are as follows:

* ATS: Although its combined electrodes offer the largest reduction in electrode consumption, the high investment and production costs make it unattractive for clients.

* Stelko: This system is the most economical, but the differences in the net savings compared with Electrotermia (US $0.91/ton) must be balanced with considerably higher investment costs.

* Electrotermia: This system is the most attractive as it offers a 20-25% reduction in electrode consumption with minimum investment.

4. ORGANIZATIONAL FORMS AND STRATEGIC DECISIONS

The process of creating, implementing and developing the method for protectively coating electrodes has been attended by various organizational forms.

DEVELOPMENT STAGES TECHNOLOGY	PERIOD	ORGANIZATIONAL FORMS	TYPE OF ACTIVITY
1. Idea of method principles	1958	Author	Fundamental research
2. First coatings	1960-64	Laboratory within metallurgy plant	R&D and Ap. research
3. Al coating	1968-70	"	"
4. Fe-Ni Coating	1982-85	Electrotermia Company	Fundamental, R&D research & applied studies
5. First model machine	1960	Within metallurgy plant	
6. Flow line	1970	Metallurgproekt Company	
7. Automatic lathes	1975-86	Electrotermia Company and Metal Machines Company	

The innovation process of idea creation, technology creation, equipment creation, domestic commercialization, foreign commercialization has passed through the following organizational forms:

* Research laboratory at the Metallurgy Company: all R&D activities during the period 1960-70 were carried out under this organizational form, financed by the "Technical Development" funds of the company. The staff received salaries commensurate with the metallurgical industry.

* Department of the Research Institute for Ferrous Metallurgy (RIFM). After the Al-Si coating was developed and its efficiency proven, it was decided to create a production shop to fulfill domestic needs. The shop was located in another metallurgy company in existence before the laboratory was closed and the department at the RIFM set up. The department

existed until 1975 and employed 12-15 people, not sufficient to perform extensive R&D activities. Within the framework of one unit working on the global problems of ferrous metallurgy, research on protective coatings was a side activity. Separating production from research activities deteriorates the relation "science-service-production" and negatively affected quality.

Thus, the organizational structure of the research unit needed to reconsidered, and a research laboratory called Electrotermia was created. In 1980, this developed into the company Electrotermia, which is presently involved in:

* R&D activities,
* Designing production shops for protective coating,
* Designing and producing equipment,
* Delivering, assembling, and putting into operation "turnkey" shops, as well as training personnel,
* Training staff to service (technologically) clients' plants,
* Producing protective coatings for domestic and foreign needs,
* Conducting side activities for better graphite utilization.

The commercial activities are performed on commission terms by a specialized trade organization which sells licenses. In agreement with the relevant norms, the trade organization acts as a partner when joint ventures are set up in other countries.

The existing organizational structure does not provide the necessary conditions for quickly realizing the results of fundamental and applied research on international markets. This is due first of all to the difference in the organizational subordination of the unit which creates the product and those which sell it. This situation leads to:

* lack of sufficient competence in implementing the technology's market policy,

* realization of the marketing strategy independently of the producer,

* difficulties in directing investments,

* insufficient economic linking of business interests along the "research-implementation-sales" chain.

In this respect, the experience of the "Technology of Metals" company must be evaluated positively. There, after an initial period of using the services of an independent trade organization and feeling the limitations of such a structure, the producer created a foreign trade unit within its own structure to deal with the sale of scientific products. Similar cases are those of Pharmachim Company, the Medical Academy, etc., where special trade organizations were created to accelerate the transfer of the product to the market.

Shortly after the Electrotermia Company was created in 1980, it began to build up its production facilities. The new organizational form favorably influenced the sales of the group of patents (Table 1 shows the main economic indicators for the period 1975-1986).

As noted above, important scientific and technical problems were solved during the period 1975-1987 in order to diffuse the method quickly. At the same time, the company's intensive development shows that the existing form has already become outdated. A change is needed in order to extend further the breakthrough already achieved and to maintain the growth rate.

An essential weakness of the existing organizational form is that the enterprise was set up as a small-scale company within the system of the Metalurgia Corporation and therefore has no authority to perform independent commercial activities. This has created a complicated and contradictory system of relations, a lack of unified interests, social tension, unnecessary expenditures, and efforts to take activities away from the company. The import of electrodes, for example, is performed by one trade organization, Rudmetal, while the export of licenses is performed by another, Technika. Joint ventures are created on behalf of Technika which defines their commercial and technical policy.

The existing structure makes it impossible to form a global market strategy for the scientific product and decreases the flexibility and strategic planning. The present organizational form acts as a limiting factor in the following directions:

* does not create conditions for coordinated development of fundamental and applied studies,

* does not provide conditions for developing a general strategy, integrating management, planning and sales,

* does not provide opportunities for a unified strategic policy in the field of protective coatings,

* reduces the efficiency of the investment process,

* does not create the necessary organizational conditions for extending the technological breakthrough on a global scale.

Further extending the technological diffusion and maintaining Bulgaria's leading position in this important field of electrical metallurgy requires a unified strategy, management, planning and sales, i.e. the creation of a common interest in all spheres, including shared attitudes and ways of thinking.

In order to create real conditions for developing the method under the conditions of the Bulgarian economy, it is necessary to create a business organization able to make its own strategic and developmental decisions and to realize them by:

* allocating and re-allocating financial and material resources,

* establishing direct links with international markets in order to sell the method and purchase graphite electrodes for Bulgaria, and also in order to conduct market studies,

* creating its own research potential,

* creating joint ventures abroad for quick and efficient diffusion of the method,

* organizing production and sales of protected electrodes in neighbor countries, using existing facilities for a service network,.

The markets for protective coatings can be divided, generally, into "near" and "distant." The near markets are Yugoslavia, Romania, Greece, and Turkey. For geographical reasons and low transportation costs, it is profitable to fulfil their needs with electrodes produced by the Electrotermia production facilities. This market, already studied by the company, consists mainly of small businesses which would hardly be in a position to invest resources to build their own shops. Greece, Turkey, and Yugoslavia are the closest markets in which very little has been done to sell the method. They consume about 22,000 tons of electrodes annually. Because of their proximity, these countries can be supplied with products produced in Electrotermia's new production facilities in the first stage of market penetration. Only after having gained a significant market share (20-25%) would it be reasonable to establish joint ventures or seek a firm to create production facilities in these countries (licensee firm).

Among the Socialists countries, Poland, Romania, and the German Democratic Republic remain markets which Bulgaria has not yet penetrated. Successful demonstrations have been done in the GDR, while only initial contacts have been established with Poland. Both countries produce electrodes which partially fulfil their needs and, despite the international price situation, are interested in using a method which will help them save hard currency by reducing Western imports.

The strategy for more distant markets must be directed mainly to creating joint ventures, in which case the income from royalties will be accompanied by a percentage of the profit.

The further successful realization of coating electrodes can be achieved under the condition that the production shops already created be reconstructed and modernized. Thus, with very little capital investment, it is possible to increase the productivity of the machines by about 25-30%. If this is put into practice, the price of the product would be reduced and quality would be stable, which will compensate to a large extent for the present market stagnation.

The research strategy should also be developed further. It must be directed to more in-depth examination in the field of protective coatings. The new directions developed by the various separate parts of the technology must be improved and brought to realization, because some of them possess qualities which will fulfil requirements of foreign markets as well.

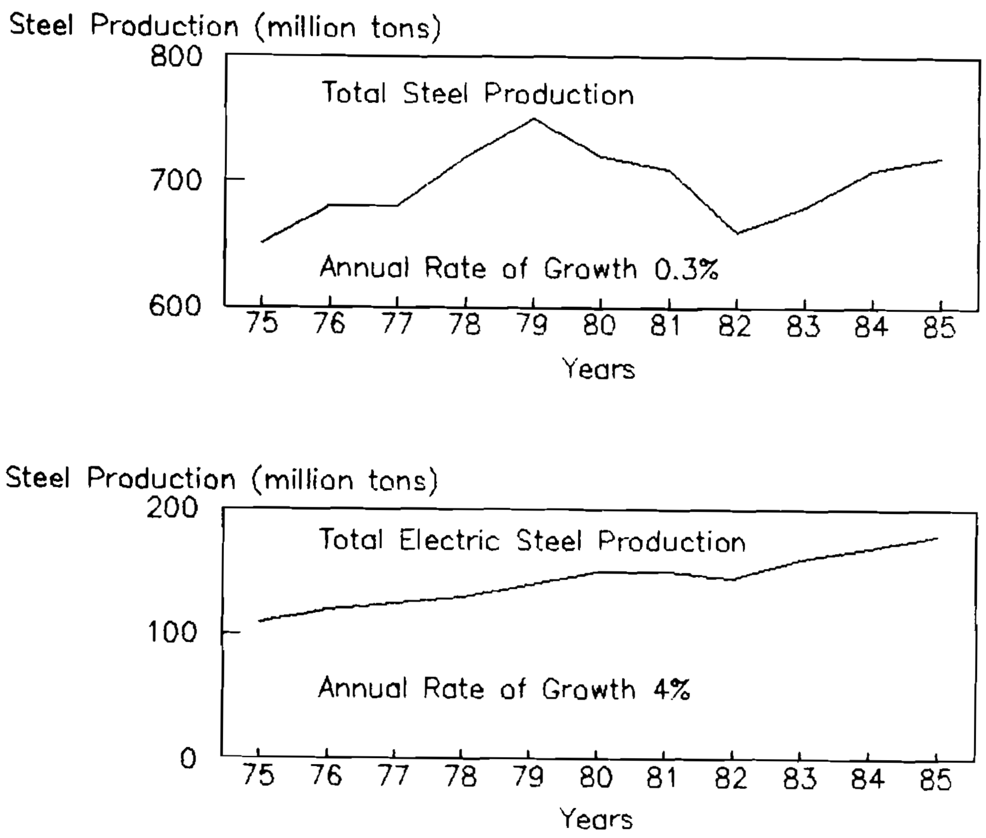

Figure 1: World Steel and Electric Steel Production

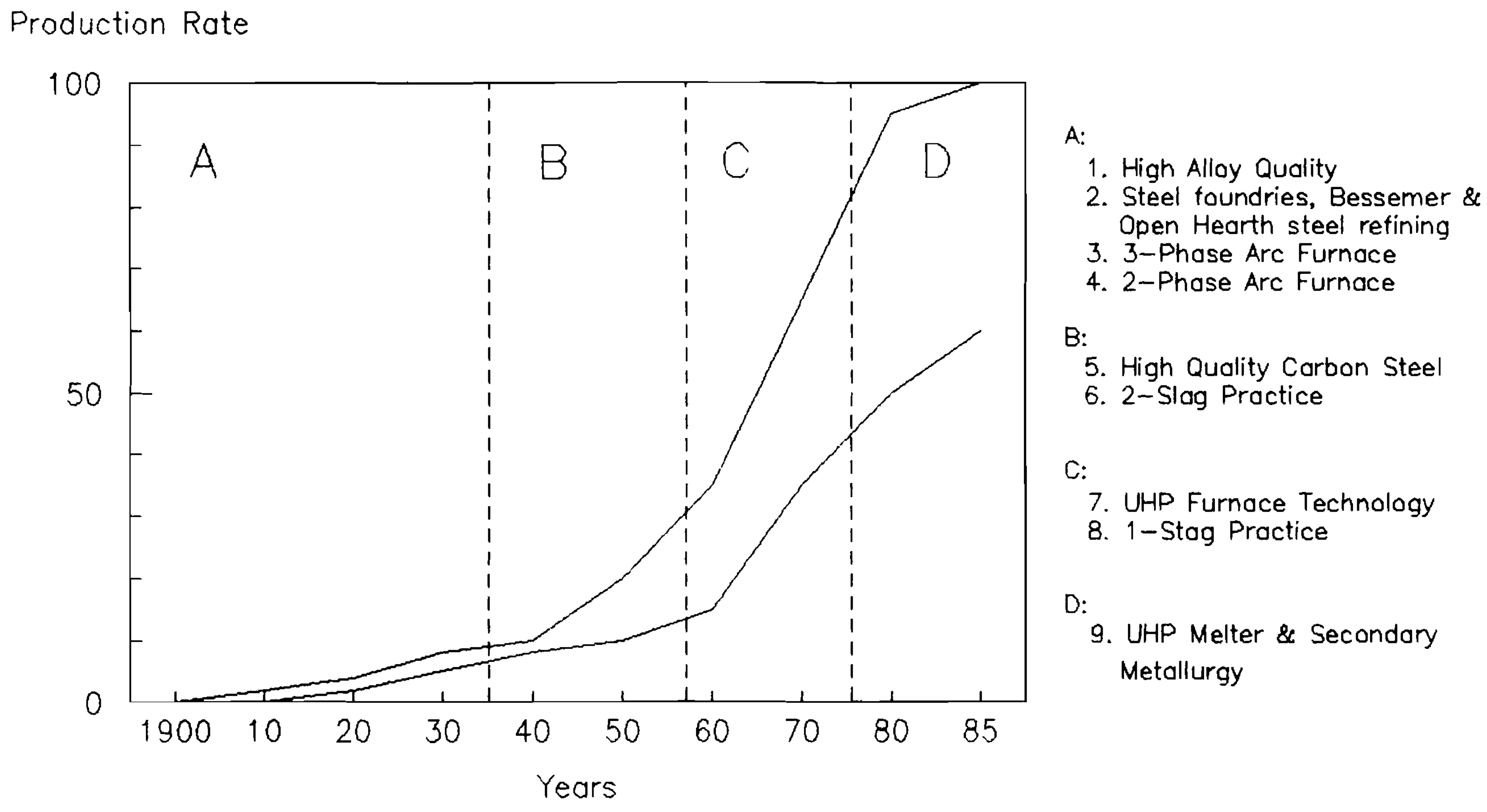

Figure 2: The Four Major Periods of Electric Arc Furnace Development

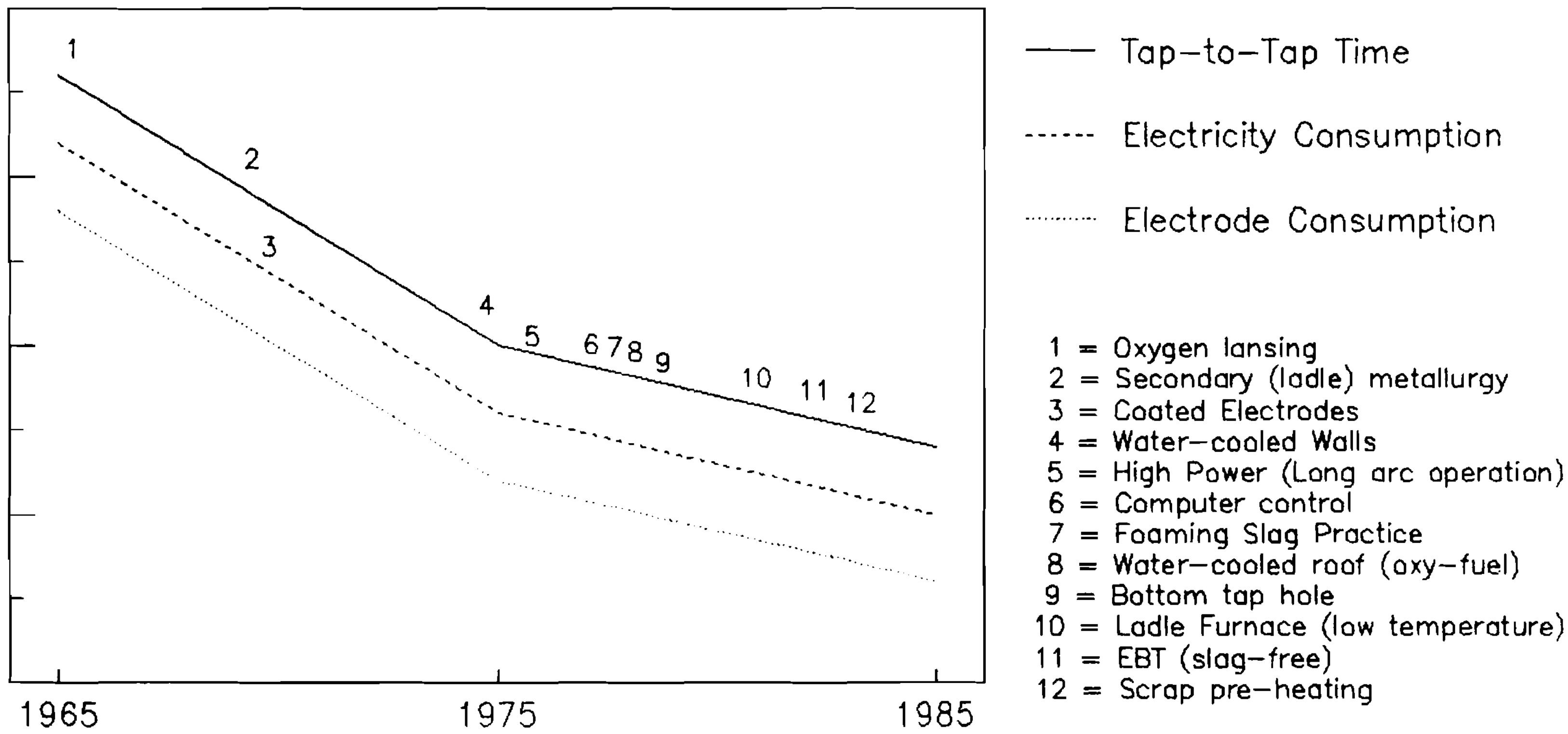

Figure 3: Influence of Arc Furnace Technology on Main Operating Parameters (1965–1985)

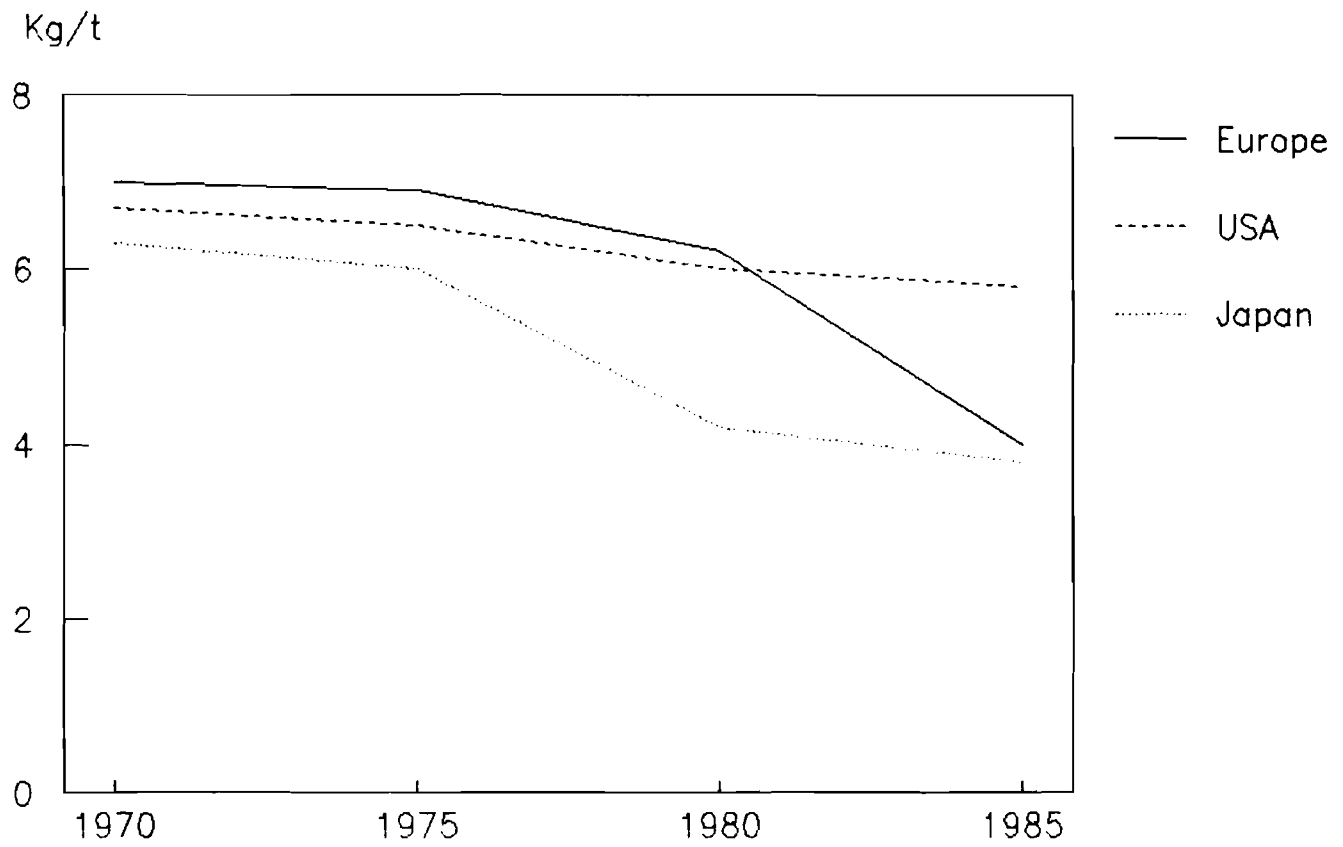

Figure 4: Graphite Electrode Expenditures in Europe, USA and Japan

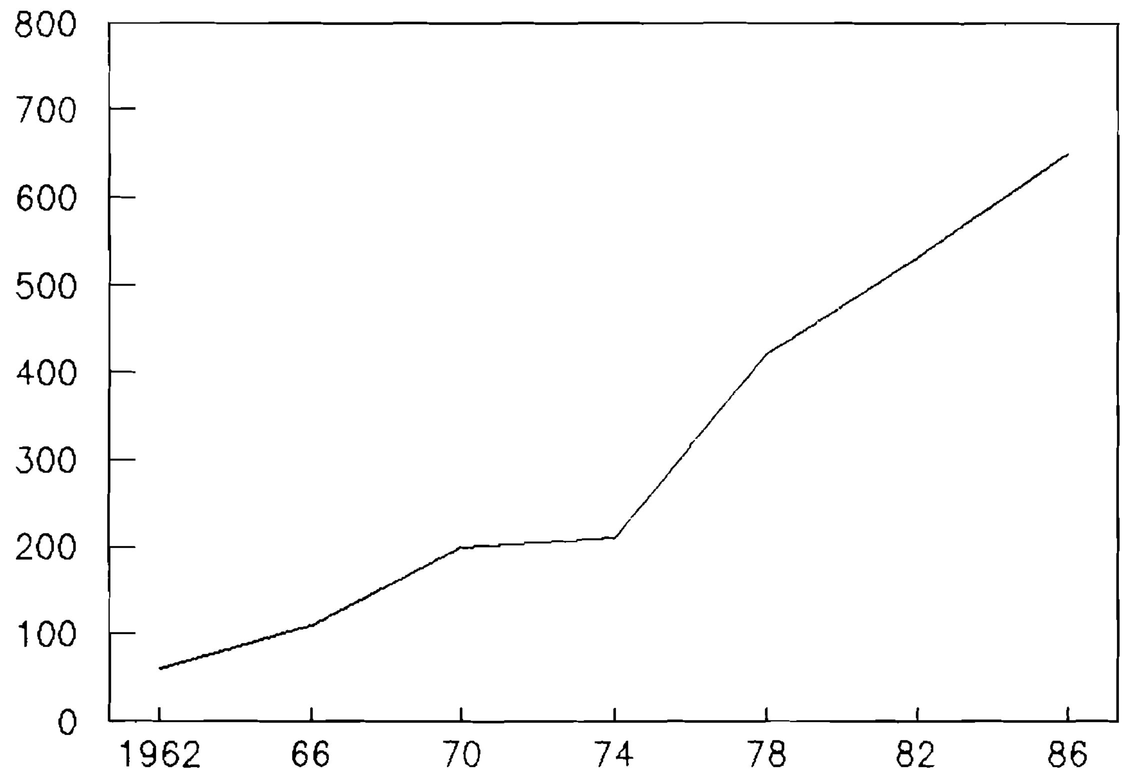

Figure 5: Coated Electrode Production in Bulgaria

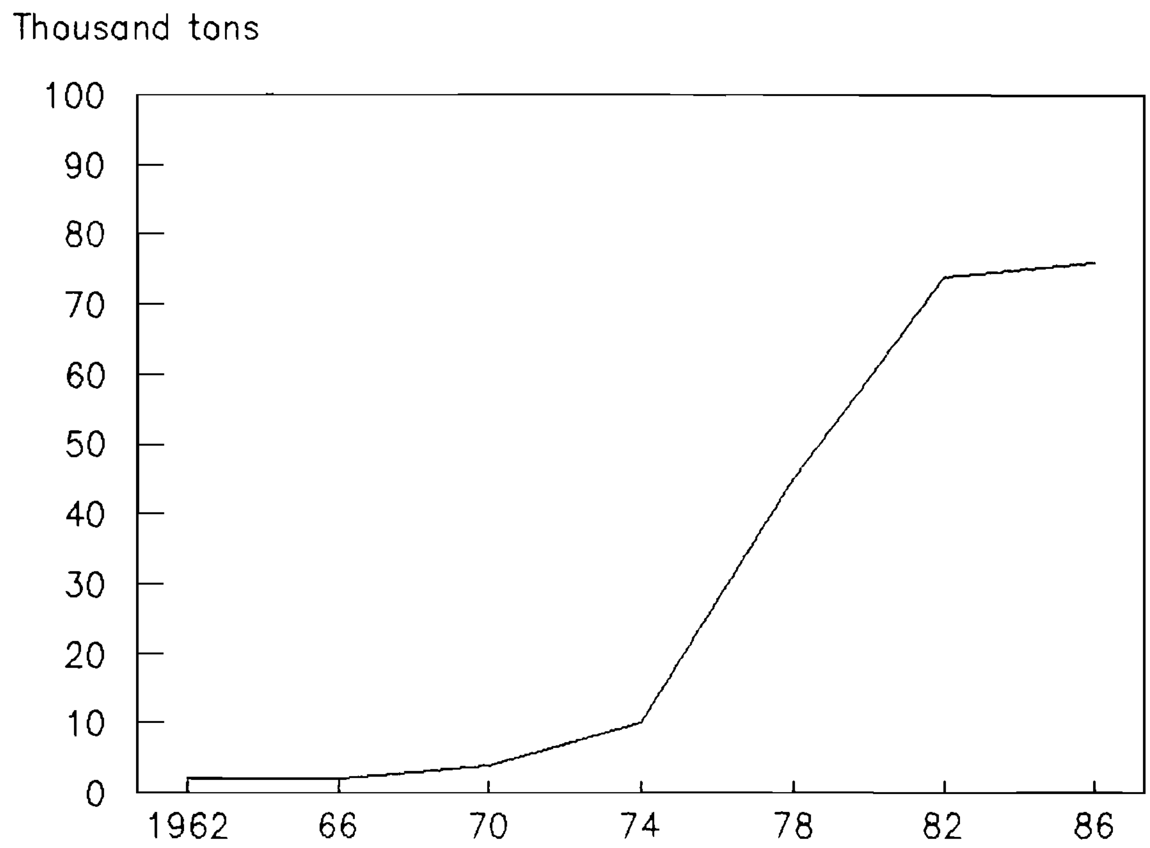

Figure 6: World Production of Coated Electrodes

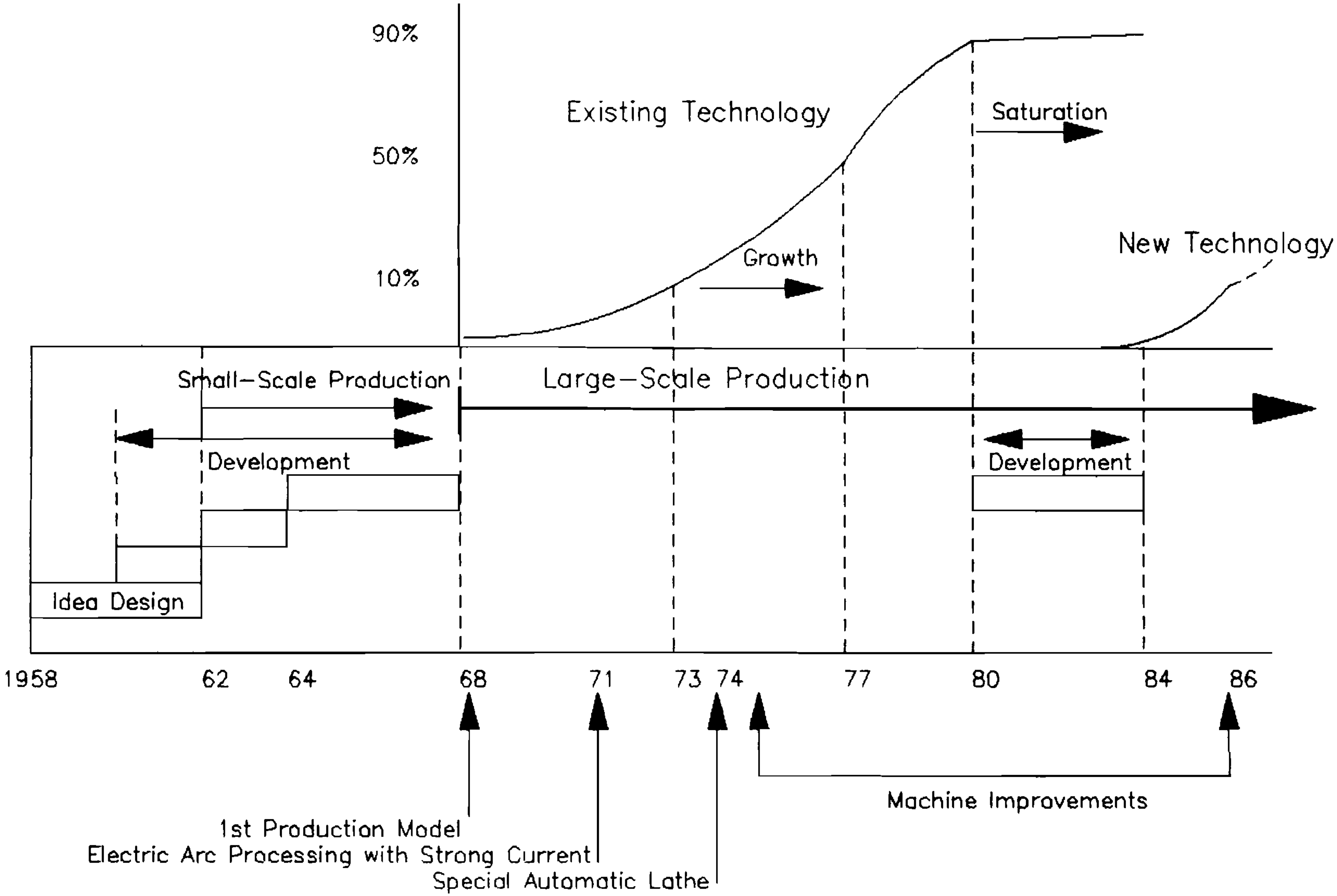
90%
50%
10%
Existing Technology
Saturation
Growth
New Technology
Small-Scale Production
Large-Scale Production
Development
Development
Idea Design
1958
62
64
68
71
73
74
77
80
84
86
Machine Improvements
1st Production Model
Electric Arc Processing with Strong Current
Special Automatic Lathe

Figure 7

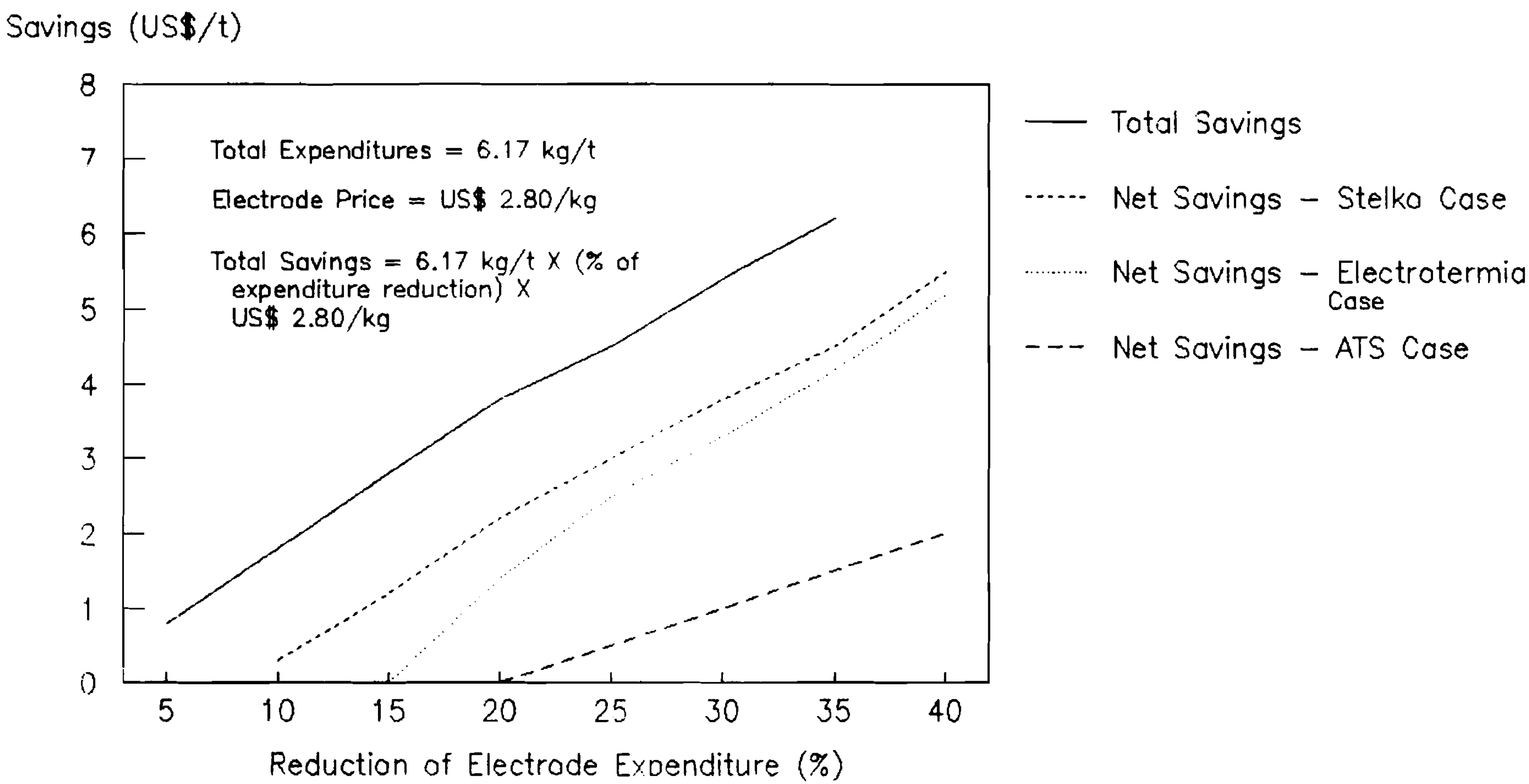

Figure 8: Savings due to Reduction of Electrode Expenditures (Based on 1987 calcuations)

TABLE 1: COMPANY PERFORMANCE (*)

(percentages)	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Profitability (**)	87.17	93.93	92.76	92.48	92.18	101.52	95.99	97.71	96.75	96.49	95.30	96.43
Royalty	100	269	213	251	349	241	212	260	295	228	233	377
Income from Sale of Equipment	--	--	100.0	22.0	18.5	--	14.3	4.6	24.9	--	26.4	9.6
Income from Technical Services and Consulting	--	100	116	102	466	76 180	238	75 64	26 165	85 544	64 301	234
Profit	100	87	211	260	262	-60	167	100	173	182	234	238
Coated Electrodes in Bulgaria	100	116	153	185	178	181	173	182	242	265	275	288
Coating Production in Bulgaria	100	103	111	133	132	134	122	121	152	165	180	185
Sales in Bulgaria	--	100	117	144	140	165	177	174	213	208	200	266
World Production of Coated Electrodes	100	214	284	365	450	479	519	585	601	609	611	621
Fixed Assets	100	101	116	119	115	99	176	224	230	242	257	275
Total Employees	100	182	202	206	202	204	206	206	204	211	206	202
Workers	100	185	195	185	275	185	180	175	180	195	185	185
R&D Personnel	100	180	208	224	144	220	228	232	224	224	224	216
R&D Expenditures	100	107	110	189	220	182	178	228	231	242	--	--

(*) these figures are representing growth rates

(**) measured by the ratio of total costs to 100 leva production

MANAGEMENT AND TECHNOLOGY LIFE CYCLE: THE TECHNOLOGY FOR THE PRODUCTION OF FANCY YARNS "PREDIMA"

M. Dimitrov, P. Phillipov, L. Glushkov, M. Ivanov[1]

1. BASIC METHODOLOGICAL PRINCIPLES AND OBJECT OF INVESTIGATION

The present study is part of the studies being carried out within the framework of the "Management and Technology Life Cycle" (MTL) project and its international network within IIASA's TES program. From the group of original Bulgarian technologies, presented here is the technology for producing worsted fancy yarns called "Predima." The main results of the study have been discussed and agreed upon by an Experts Committee.

1.1. Methodological Principles of the Study

The study aims to reveal the characteristic features of the innovation process connected with the new technology predima, to analyze the problems of technology development of a system for its management, and to formulate conclusions and recommendations for management improvement, as well as for the goals of technology development.

The study is oriented into two main fields:

* analysis of technology dynamics and assessment of the development of the technology and

* analysis and assessment of the management of the technological process from the creation to the implementation and development of the technology.

The study was structured in several stages, differentiated on the basis of their various tasks in the following way:

Stage One: Description of the state of technological development and of the system for its management for a selected past period. Definition of problems related to the management of technological development.

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1 Dr. Milko Dimitrov and Mr. Phillip Phillipov are both from the Predima Company. Dr. Lubomir Glushkov and Mr. Methodi Ivanov are both from the Institute for Social Management, Sofia.

Stage Two: Definition of the future development of the technology and the studies for accelerating this process, with recommendations for applying suitable organizational strategies and form and management methods.

The main task of the first stage is further broken down into a certain number of sub-tasks, the most important of which are:

* to trace and analyze the life cycle of the studied technology;

* to specify the place of the technology among its competitors;

* to trace and analyze the organizational forms and the main characteristics of the management system accompanying the development of the technology.

In order to obtain the results necessary for management practice, the study aims to answer two main questions:

* What must management know about technological development in order to be able to orient it and accelerate it in the right direction?

* How can the existing theories about the regularities of technological development and of the innovation processes help to improve the system of technology management?

In order to provide management with organized knowledge, the development of the technology was studied from its creation to its practical application. Technology dynamics is an objective basis for defining the common and the specific aspects of technological development.

The empirical testing of the famous hypothesis that the management system and its elements change depending on the stage of technological development is necessary to improve management.

The analysis of technology dynamics is based on the study of the technology life cycle and the stages in its creation and development. Various indicators are used to build up the life cycle. They can be formalized by differentiating, through content analysis, the life cycle phases depending on their dynamics.

The indicators for constructing the life cycle are selected depending on the goals of the study. Very often the life cycle curve gives only a general idea about the development of the technology. When using only this approach to the analysis of technology dynamics, and when a limited amount of quantitative data is available, it is not always possible to do a deep analysis of the basic features of the innovation process. This limitation is stronger when the goal is to find out the problems in the system of management of the process of technological development. Therefore, the analysis of technology dynamics is done using the stages of its creation and development as well as its main characteristics.

The final conclusions about technology dynamics are reflected in the relation between the two main dynamic characteristics: the life cycle and the stages of technological development.

Technology assessment is directed to defining a technology's place in comparison with competitive technologies in terms of their main technical characteristics. By doing a comparative analysis of the main elements of the technology, certain conclusions are reached about its competitiveness and potential. An important aspect in assessing the technology is defining its significance for the business organization which creates and implements it and for other business organizations and the national economy as a whole. The degree and directions of its diffusion and the multiplication of its effects determine both the limits and the potential of the technology.

The analysis and assessment of the management of the technological innovation process is done in several cross-sections according to the stages in the creation and development of the technology:

* analysis of the organizational forms with regard to the subject of activity, subordination, and relations with superior authorities and with subordinate and associated units;

* analysis of the strategic decisions, the level at which they are made and approved, and the degrees of their realization in the organizational units;

* analysis of the economic conditions in which the organizational units function: economic mechanism, financing, planning, motivation, etc.

The results from the second direction of the study are necessary in order to determine the advantages and disadvantages of organizational and management forms and methods at each stage of the development of the technology, to formulate conclusions to improve the management system under conditions of accelerated technological development.

1.2. Object of the Study

The object of the study is the process of creating and development the technology for producing worsted fancy yarns known as Predima based on an original Bulgarian invention entitled "A

Method and Equipment for Production of Core-yarns" by Dr. Milko Dimitrov, which is patented in 13 developed industrial countries in Europe, Asia and America.

"The method and equipment for production of core-yarn" has been used as the basis of some fundamentally new technologies in the field of producing worsted fancy years with better technical and economic characteristics of the technological process.

The predima technology is designed for pneumatic spinning of low and medium count yarns from wool, chemical fibers, and mixtures of the two. It offers constructive and technological opportunities for increasing productivity several times as compared with classical spinning. The yarn thus produced is used to make knitwear articles and fabrics.

The predima technology is a new concept for yarn-making. Staple filaments, drawn in the standard way, are twisted around the core of two filament fibers or around a core formed from the two filament fibers and staples, thus obtaining yarn with a good appearance and pleasant touch.

The bulk of the yarn provides good coverage with different weaves and patterns and makes it possible to produce light articles with good properties. A typical feature of the technology is the possibility to obtain a variety of bulk and color effects. Up to 72 color combinations in the final product are possible.

What is particular to this study is that at present the entire innovation process -- from the idea of a new technology to its implementation in production and dissemination in the country and abroad -- is realized in one business organization. The Novotex combined works closes the invention-implementation-production cycle. This makes it possible to react quickly to changing market demands, to shorten the implementation stage and to control product quality more efficiently. The firm's task is to create new machines and technologies in the textile industry, to produce and export machines and textile products, to sell know-how, and to perform commercial and engineering activities domestically and abroad.

The coincidence of the object of the study, i.e. the process of creating, developing and transferring the new technology, with the activities of the firm allows the study to concentrate within the frame of the technology in full agreement with the goals and organization of the study at the present stage.

2. TECHNOLOGY DYNAMICS

2.1. Technology Life Cycle

The life cycle of the predima technology is constructed on the basis of the following indicators:

* sales volume of the technology expressed through the sale of machines, textile products, and know-how;

* production volume of products made by means of the technology in Bulgaria and in other countries and the market share of the products.

2.1.1. Sales Volume: Machines

The study of production and exports covers the period from 1984, when the regular production of Predima-8 machines from the Predima family was started (the technical characteristics of the Predima machine are found in annex 2).

The internal demand in the Novotex firm for Predima-8 machines was satisfied by 1986. After this period, the main portion of the machines as an element of the technology was directed to exports.

The Predima-8 machines are produced in the R&D department located in the town of Gabrovo and the "May 1st" factory in the town of Kazanlak. The annual production capacity at the present time is 16 machines. The data for this period are given in Figure 1.

The data show that for the last 3 years, the production and sale of machines have remained the same and that the production capacity was fully used. The lack of changes in the production volume does not mean that the volume of machines will remain the same in future. The reason for the drop in 1986 is that there were some organizational problems related to the transfer of certain production activities from one factory to another, and the new producer did not possess enough experience in machine-building nor enough trained personnel.

The newly created machine-building production capacity releases resources which are directed to extending R&D activities. Until 1987, no Predima machines were exported because it was necessary to fulfil internal demand.

During this period, the domestic demand for final products (yarn, textile products) helped the firm reach its economic goals. Therefore, not attempts were made to break through to the international market for machines.

The spinning machines produced until 1987 were sufficient to satisfy the firm's own needs for producing fancy yarns with the Predima technology.

2.1.2. Sales Volume: Yarns

The production and export of yarns produced with the Predima technology was studied for the period after 1985. The data for the period under review show growth in the volume of production (see Figure 2).

This tendency to increase production will continue because of the wide application of the Predima yarns in the textile industry, the strong interest of Bulgarian and foreign consumers of yarns, the varied assortment of textile products, and the good economic results.

2.1.2. Sales Volume: Textile Products

The production of textile products from Predima yarns covers the period from 1985. The data for the period show a growth in the production of knitwear products (see Figure 3).

The production of textiles from Predima yarns covers the period from 1986. It was done mainly by other firms in the sector and has the following growth rates (shown in Figure 4):

The data which characterize the technology show its development during the first two phases of the life cycle: infancy and rapid growth. The expenditures are predominantly for R&D during the first phase and for creating production capacity during the second.

This is also confirmed by the data on the composition of staff: mainly designers and technologists, with a few production people during the first phase and an increased number of production people during the second.

The data for production and sales do not provide reasons to believe a saturation phase is approaching. On the contrary, marketing studies reveal both new needs in the traditional final products and new market niches.

2.2. The Stage of Technology Creation: Machine-Building

An important stage in the development of the Predima technology is the creation of the machine which executes it. The first model of the Predima-8 machine was created during the period 1981-1984. Based on it, a family of machines was created together with developing the technology itself.

Until 1984, the firm implemented predominantly R&D activities aimed at creating this machine. Figure 5 shows the dynamics of total expenditures for R&D activities throughout the years.

There is an obvious tendency to reduce the expenditures relatively during the transition to the next phase of the life cycle. The year 1986 was an exception as a new modification with 16 working heads was created with improved technical characteristics.

A comparison with Figure 2 shows the link between the results from R&D and production activities.

In the course of the study, it was found reasonable to analyze the structure of expenditures for creating the machine, because the specific nature of the closed cycle in the firm determines certain peculiarities. The necessity to make modifications and create new machines requires knowledge about the structure of R&D expenditures (see Figure 6).

The largest expenditures were for making the test model and for the design and construction of instrumental equipment.

It was discovered in the course of the study that in spite of the small share of expenditures for constructing the functional model (8%), this process engaged the staff with the highest qualifications.

The share of the expenditures for instrumental equipment (32%) corresponds to that for constructing the test model (31%). It is typical that the expenditures are mainly directed to specialized firms.

The expenditures for producing the documentation (15%), according to the experience of the researchers, are too high. This could be avoided by implementing automation in design activities.

2.3. Stages in Technology Development

The technology started its development after the creation of a functional model which realized the idea born in 1983 for a more efficient method for producing worsted fancy yarns. The idea is to create a spinning method which will be high speed, stable, and offer opportunities for producing yarns with different structures, thereby introducing greater variety to the product list.

Another goal is to develop a technology for producing worsted fancy yarns more quickly than the classical spinning technology (see Figure 7). This goal was reached after a number of problems had been faced: financial, technical, and technological. The main technical indicators which had to be reached during the different stages were defined:

* yarn count range,
* spinning regime,
* range of raw materials used,
* basic physical and mechanical properties of the yarn,
* expected economic effect,
* demanded qualities of the machine.

A number of difficulties were faced in the technological realization, due to the lack of adequate production facilities.

2.4. Machine-Building

Successful experiments were made in 1982 for making Predima yarns. In order to speed up the production of machines for such yarns, two functional models were produced as early as 1983, using as a basis the construction of the adhesive applying machine (a product of another original Bulgarian technology) then in existence.

The very good results which were obtained allowed the production of technical documentation and the test model in the same year.

The instrumental equipment and the test series were made in 1984, and regular production was started in the same year.

The year 1985 saw the production of new machines from the Predima family, with 16 and 8 heads and improved design and technical properties.

A further development of the Predima method was made in 1986, when the test model of the Dima machine was created. Simplicity, lowered material and energy consumption, and increased reliability are some advantages of the new machine. The test series of these machines was made in 1987.

Tables 1, 2, and 3 show the results of the following comparisons: Predima machine with Dima machine; Dima with the classical production method; and Dima with a spinning method using a hollow spindle.

Table 1.

INDICATORS	MEASURE	PREDIMA	DIMA	REDUCTION (%)
Bearing arcs	m	2.040	0.660	30.9
Electricity consumption	KW/H	1.820	1.770	2.8
Required # of operators	people	0.055	0.052	5.8

Table 2.

INDICATORS	MEASURE	CLASSICAL TECH.	DIMA	REDUCTION (%)
Bearing arcs	m	3.78	0.66	572
Electricity consumption	KW/H	2.88	1.77	163
Required # of operators	people	0.18	0.052	346

Table 3.

INDICATORS	MEASURE	HOLLOW SPINDLE	DIMA	REDUCTION (%)
Bearing arcs	m	4.41	0.66	622
Electricity consumption	KW/H	2.66	1.77	150
Required # of operators	people	0.075	0.052	144

The efforts of the management team were oriented to transfer production to other factories and to create production facilities using a tes period for the first series of regularly produced machines.

This was necessary for stabilizing the new product and exporting model machines. At the same time, conditions were created for increasing the production of finals products.

2.5. Final Product

The new technology is applied in wool spinning for producing fancy woolen yarns mixed with synthetic fibers or yarns of purely synthetic fibers.

The new method reduces the classical processes of bobbin winding, doubling, and twisting. Productivity is 6-7 times higher than in classical spinning. The technology allows a greater variety of colors for the articles made from Predima yarns.

The spinning method and the design of the Predima machine alloys the production of the fancy yarns with:

* different loading of the drawing unit and
* different speed.

These are yarns with up-rise fiber or the so-called "mohair" yarns or yarns "mohair-bouclé" (in which the mohair effect is added to the bouclé effect).

The technology was developed stage by stage in 1984, and regular production of these yarns started in 1985.

The bouclé effect is achieved by means of different fibers: silk, metal-plastic, and a variety of others. These yarns with a new structure were developed in 1986, the year which saw the production of the Predima mohair yarns. This created a considerable variety in the yarns compared with the traditional methods of spinning.

The yarn count range was 72-250 tex. These yarns were later applied both in spinning and in knitwear production. Regular production of worsted fancy yarns started in 1987.

Yarns with a new structure (the so-called worsted yarns with flame effect) started to be developed during the same year. In the case of these yarns, the flames can be external (when the group of staples and fibers forming the flame are twisted around the core of the yarn as the most external layer) or internal (when the fibers producing the flame are covered with other fibers serving to fix the flame to the core).

The yarns are bulky and create a feeling of comfort. Their bulkiness results in an economic use of materials and increases the economic efficiency of their application in the textile industry.

The constant enlargement of the product range naturally led to new developments both in the field of knitwear production and in the production of fancy materials for outer clothes. The improved design and structure and the reduction in material consumption (up to 15%) are both reasons for the wide application of the Predima yarns.

3. COMPARATIVE ASSESSMENT OF THE TECHNOLOGY

A recent novelty is the system of the French firm Chavanoz for producing fancy and smooth yarns on the principle of hollow spindles.

Later this system was developed further by James Mackie (UK), Saurer-Allma (FRG), Pa-Fa (Italy), Jantra (Bulgaria), Gemmill and Dunsmore (UK, Süssen (FRG), and Schlumberger (France). The machines for smooth yarns applying the same principle are oriented mainly to the lower counts.

Novotex developed a method for pneumatic production of fancy yarns.

The fibers 4 and 5 (see Figure 2) go into drawing unit 1 in pneumatic nozzle 3 where, drawn by the air flow, they mingle with silk 2. The pneumatic nozzle 6 stabilizes the effect and gives a hair quality to the yarn.

This method exceeds the one with hollow spindles through the following advantages:

1) The actual speed of the Novotex machine is up to 150m/min within the range from 250 to 72 tex. In addition, the thickness of the yarn is of no importance, while the hollow spindle method works with a speed of 31-90m/min depending on the type of yarn, exceeding 100m/min only in the case of coarse yarns. This is due to the fact that in order to stabilize the yarns using the hollow spindle method, it must be covered by a filament fiber and each twist made with one turn of the spindle.

   The thicker yarns are covered with a bigger auge, and the speed is therefore higher. Practically, when the speed is 100m/min, the number of twists in one meter is 400-5000, and the spindle has to rotate with 40,000-50,000 turns per minute, which is difficult especially as it is loaded with a spool of silk.

   The Novotex method for producing the twist does not involve rotating elements. Only the shafts of the drawing couple rotate.

2) The hollow spindle method requires an additional operation of filling the spools with silk, and as they are very light, it is necessary to replace them often in the course of production. With the Novotex method, the silk is taken from bobbins (there is no intermediary operation) and the time of bobbin use is considerably longer.

3) In the hollow spindle method, the silk moves in a screw-like manner, and the total length of silk in the yarn is 10% greater than in the Novotex method, where the silk is a straight core.

4) In the hollow spindle case, the silk is twisted on the yarn externally, while with the Novotex method, the silk forms the core of the yarn. This creates a better appearance and makes the yarn more functional.

5) With the pneumatic method of yarn-making, the yarn has a hair-like appearance.

6) There are wide opportunities to blend during spinning because of the absence of the homogeneous mixture of colors typical of classical spinning, and the different colors preserve their brightness.

7) The machine design allows the production of yarn on bobbins.

8) The division of the machine into heads which move independently and the presence of compensators provide conditions for reaching a practical high coefficient and machine-utilization of 90-95%.

4. DEVELOPMENT OF THE MANAGEMENT SYSTEM

In 1977, a new unit was created to develop and implement a fundamentally new technology and to design a machine to realize this technology.

During the period 1977-1979, studies and tests were made, the first functional models created, the first quantities of yarn produced by joining the fibers with adhesive. Departments of design and of technology were created, gradually gaining experience. Functional models, however, did not yet exist.

In 1980, the enterprise created a Laboratory for Research and Implementation, with a pilot machine-building plant. The statute of the producer changed as well. It became a research and production company and created some functional departments to coordinate these activities.

As a result, the headquarters in Sofia was oriented to R&D activities in the field of textiles, while machine-building as a whole was moved to another town.

In 1981 the creation of R&D and testing were started in the field of spinning and knitwear.

The beginning of a pilot spinning shop was marked by the installation of the test model of an adhesive-applying machine.

During 1980-1987, the Novotex firm was enlarged and now includes 6 independent units. A complete production cycle is realized in machine-building and all fields of woolen textiles: from raw materials to finished products such as machines, yarns for hand-knitting, outer knitwear, fabrics.

The transition from the phase of predominantly R&D activities to a combination of production and R&D activities is demonstrated by the production volumes and the changes in the composition of employed staff (see Figure 8). Starting in 1982, the number of the research and servicing staff began to equal each other, even though in 1983, there was a considerable increase in the number of employees.

CONCLUSION

On the basis of the collected empirical data, it is possible to draw the conclusion that the technology for producing fancy worsted yarns known as Predima has passed its infancy phase and is now in the second phase of rapid growth. Compared with other original Bulgarian technologies (counter-pressure casting, protective electrode coatings, etc.), the Predima technology demonstrates a relatively rapid transition from the first phase of the life cycle to the second. The authors see the explanation of this in the specific feature of organization and management of the process of technological development, i.e. the closing of the cycle "idea-design-production-improvement" and its realization in one company.

The management system which made this closed cycle possible is similar to that in many other cases. In the initial phase, the program-oriented organization is the basic one, while in the phase of rapid growth, stationary production and administrative units appear.

The results of the study provide grounds for formulating some recommendations to the company's management regarding the most efficient use of the opportunities in the present stage of technological development. This concerns most of all the formation of a common strategy for organizational development, and in particular for developing marketing and product strategies. The last two concern both the development and realization of final products, but also of machines for their production.

The further observation and analysis of the development of the technology and the organization could lead to more general theoretical conclusions and practical recommendations to the firm management.

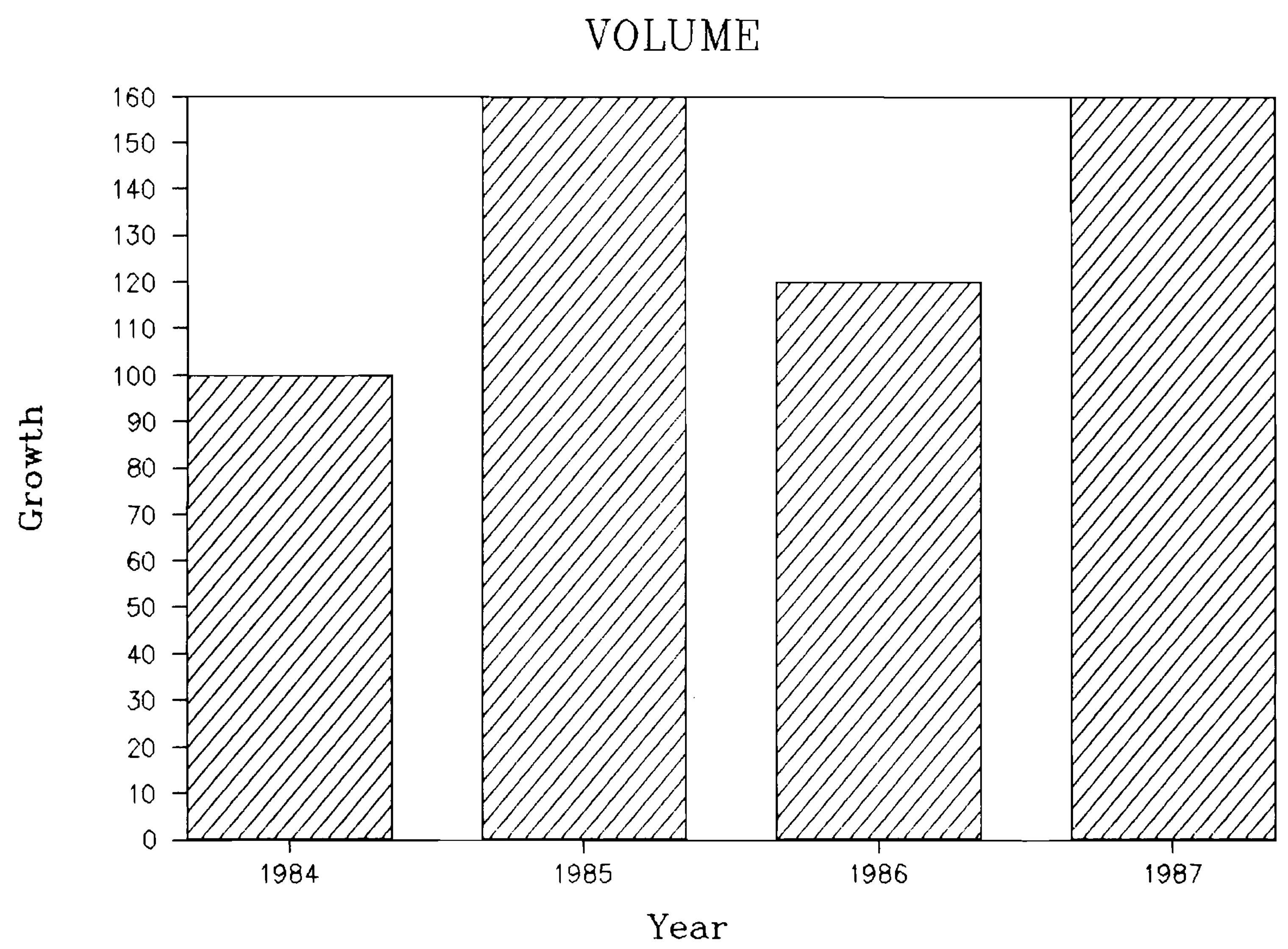

FIGURE 1: PRODUCTION OF PREDIMA MACHINES

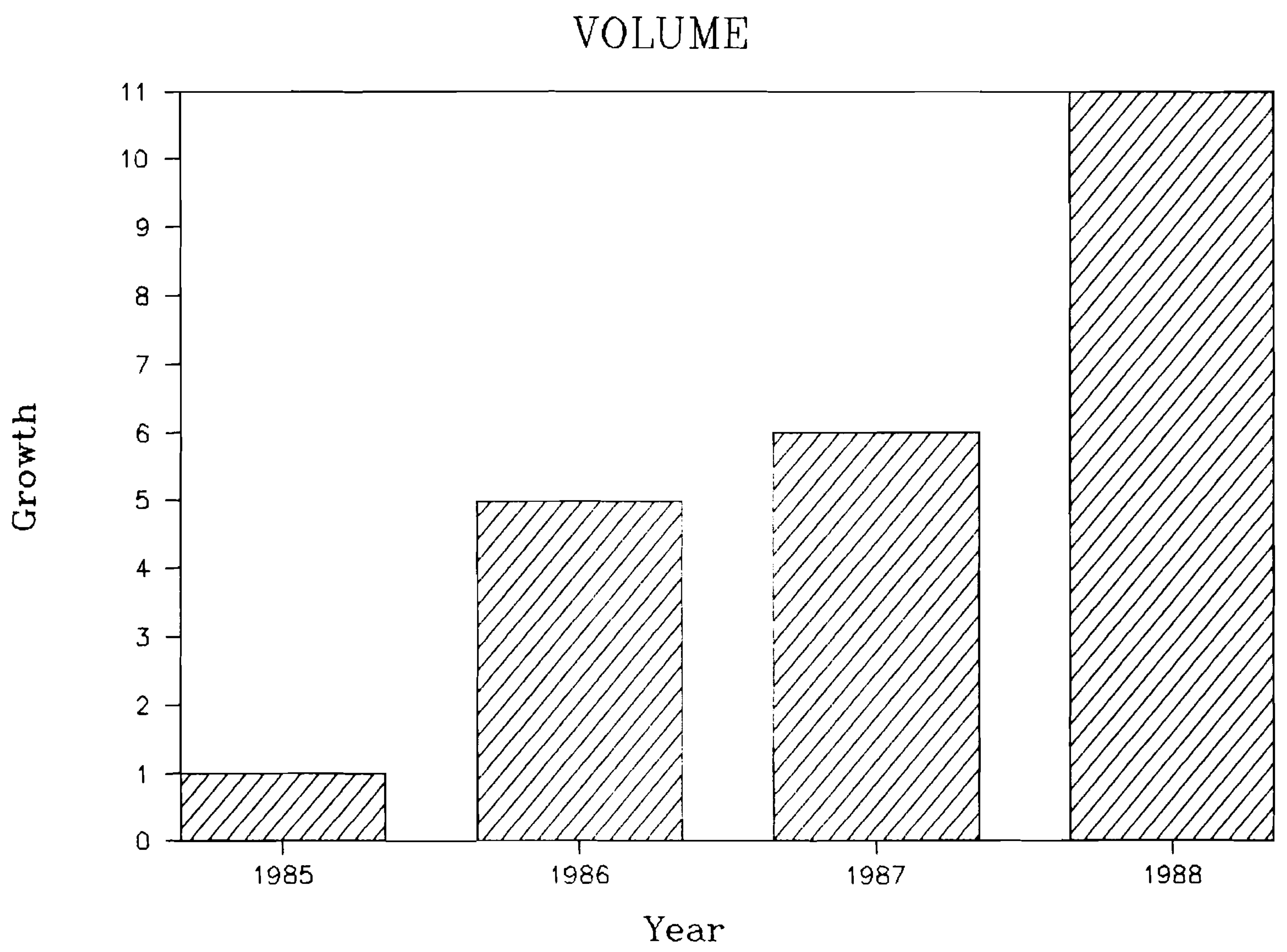

FIGURE 2: EXPECTED PRODUCTION OF FANCY YARNS

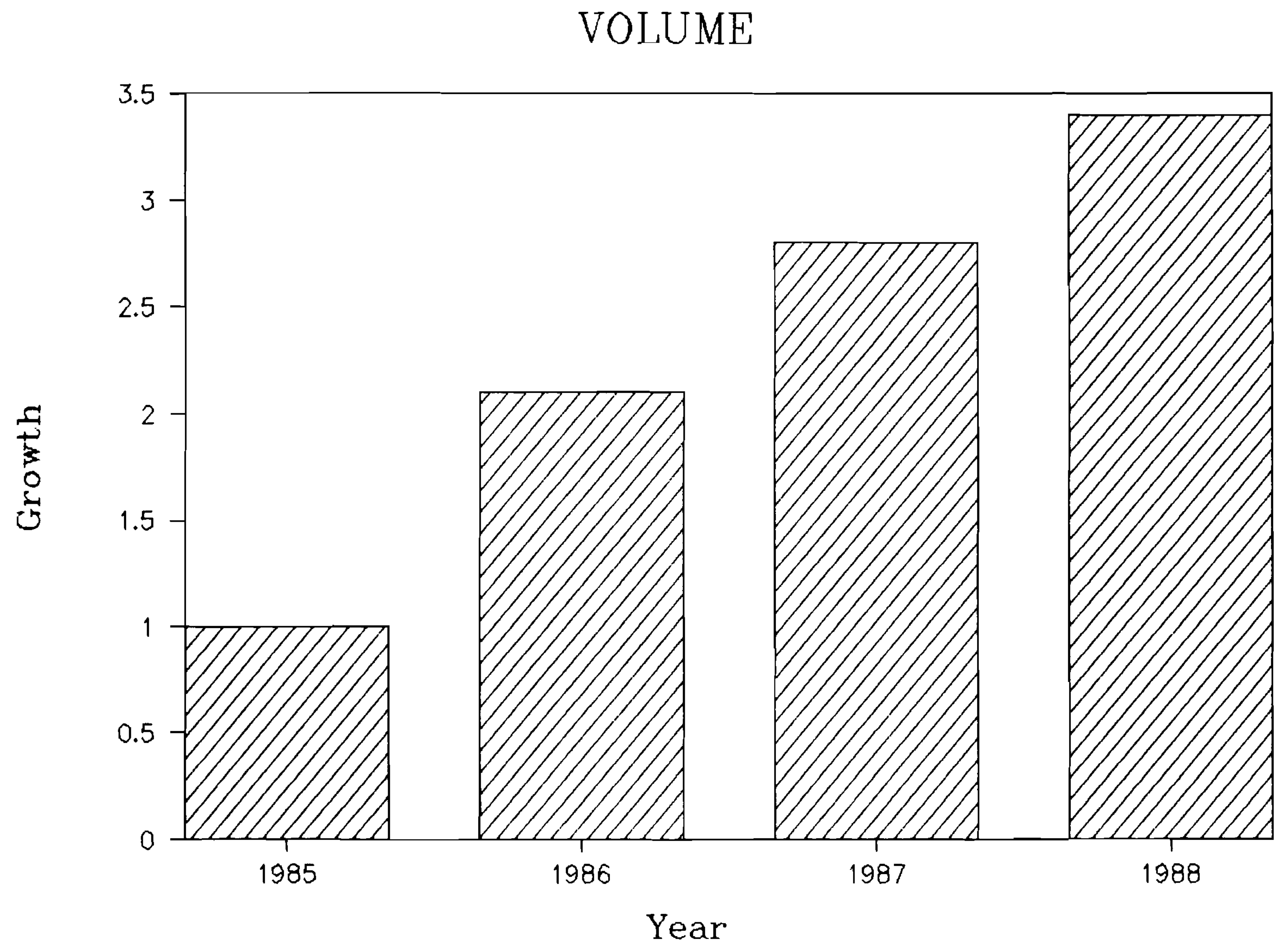

FIGURE 3: PRODUCTION OF KNITWEAR PRODUCTS

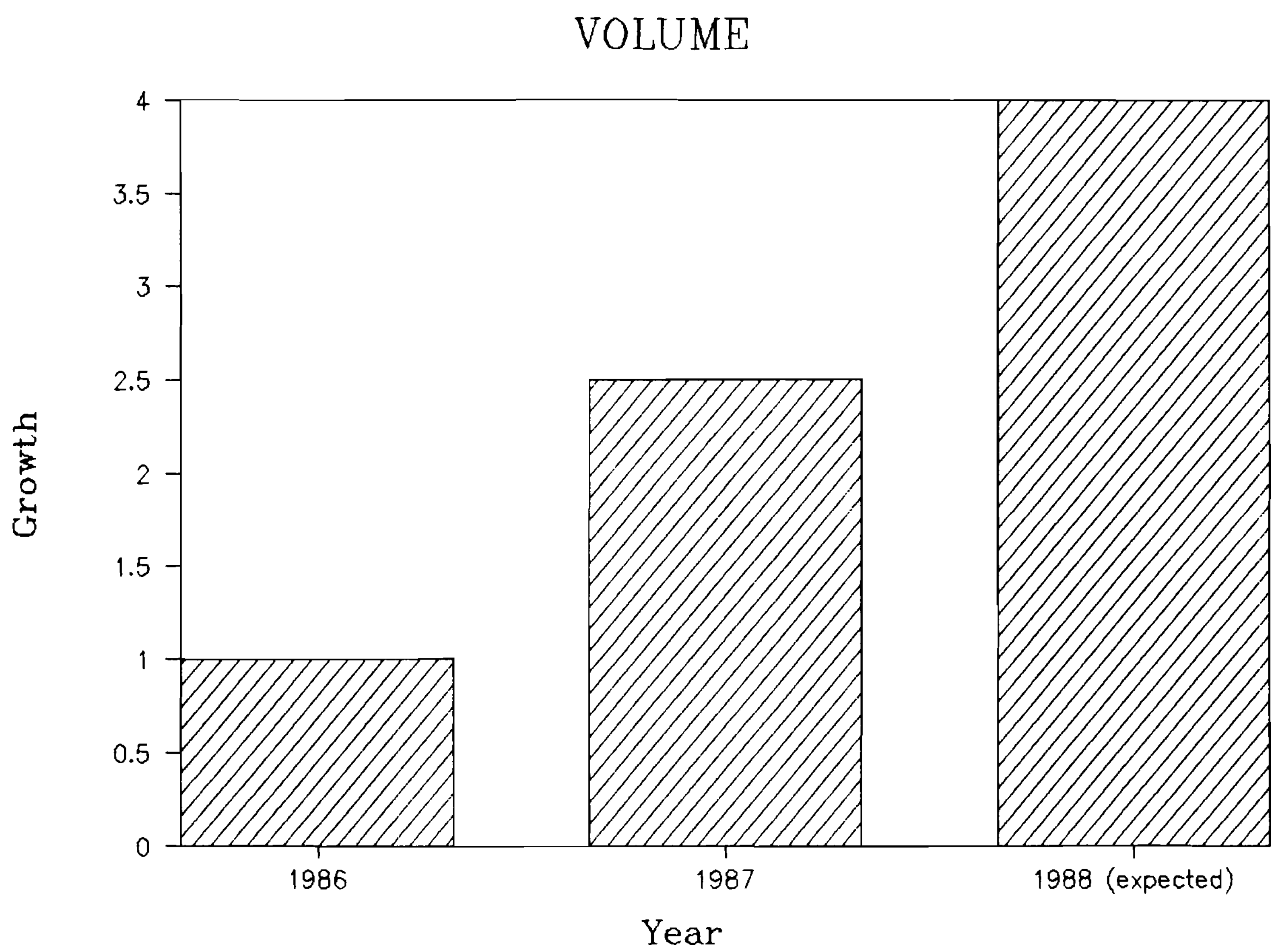

FIGURE 4: PRODUCTION OF TEXTILE PRODUCTS FROM FANCY YARN PREDIMA

FIGURE 5: EXPENDITURES FOR R&D

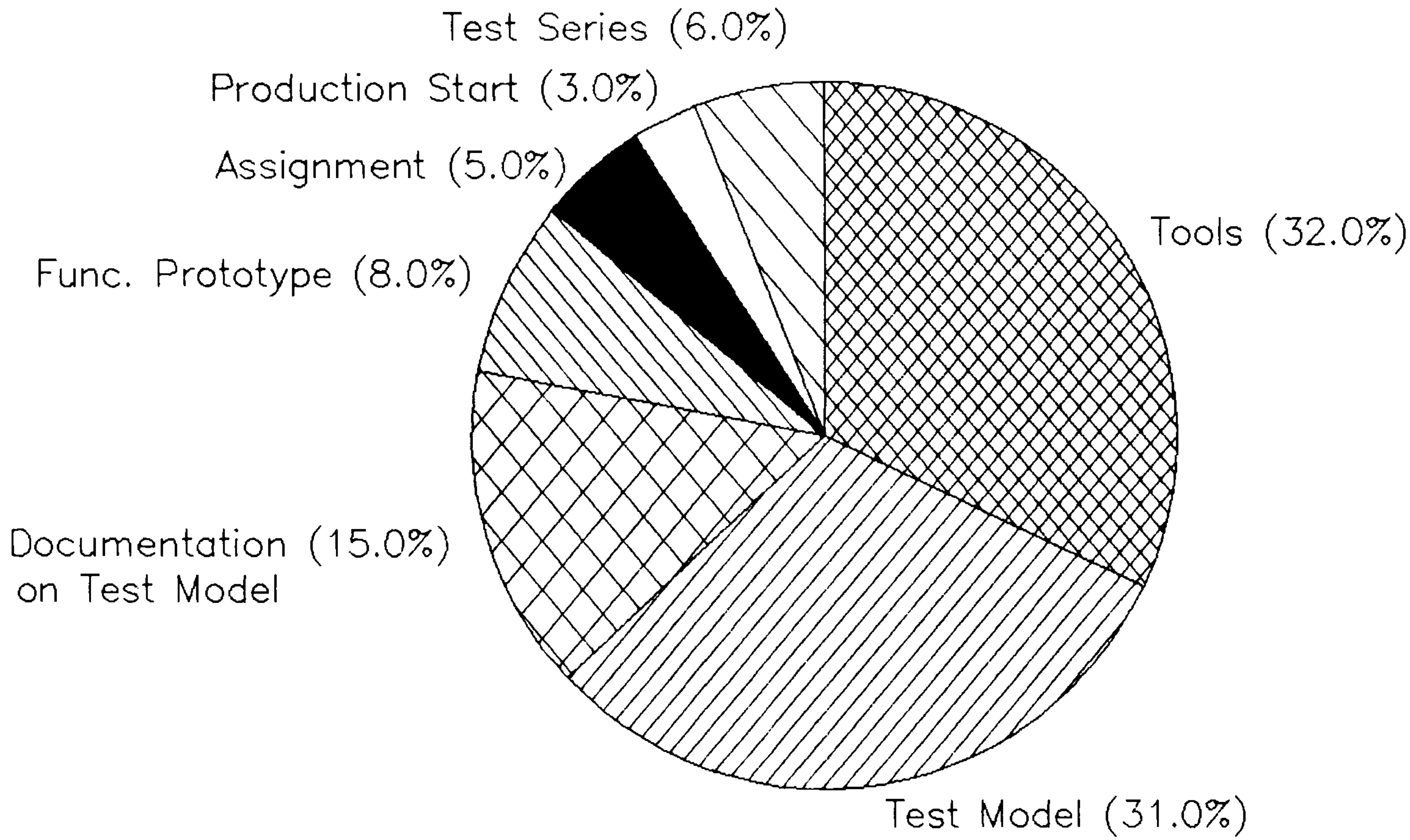

FIGURE 6: STRUCTURE OF R&D EXPENDITURES -- MACHINE-BUILDING, 1983-1987

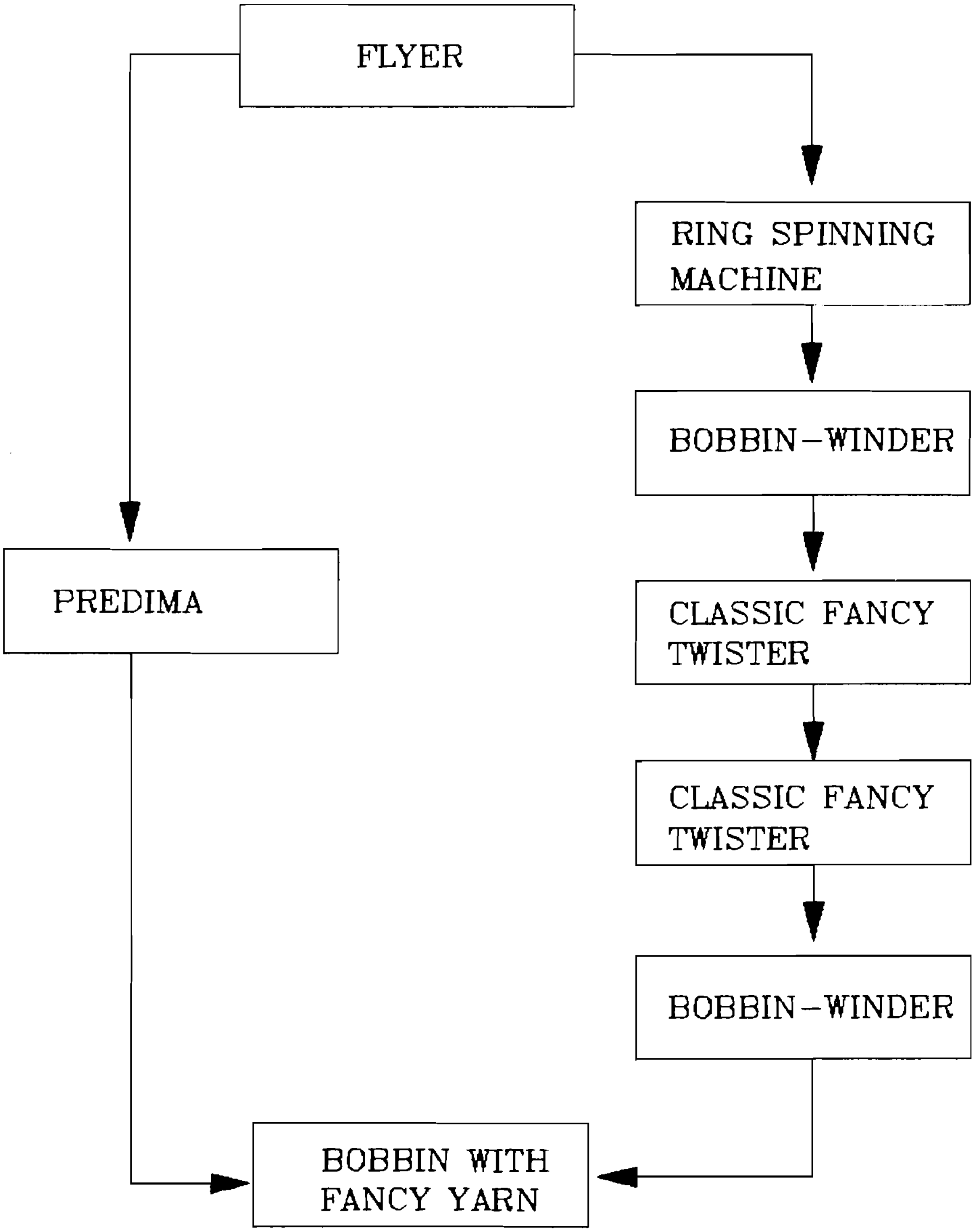

FIGURE 7: COMPARISON OF PREDIMA WITH CLASSIC METHOD

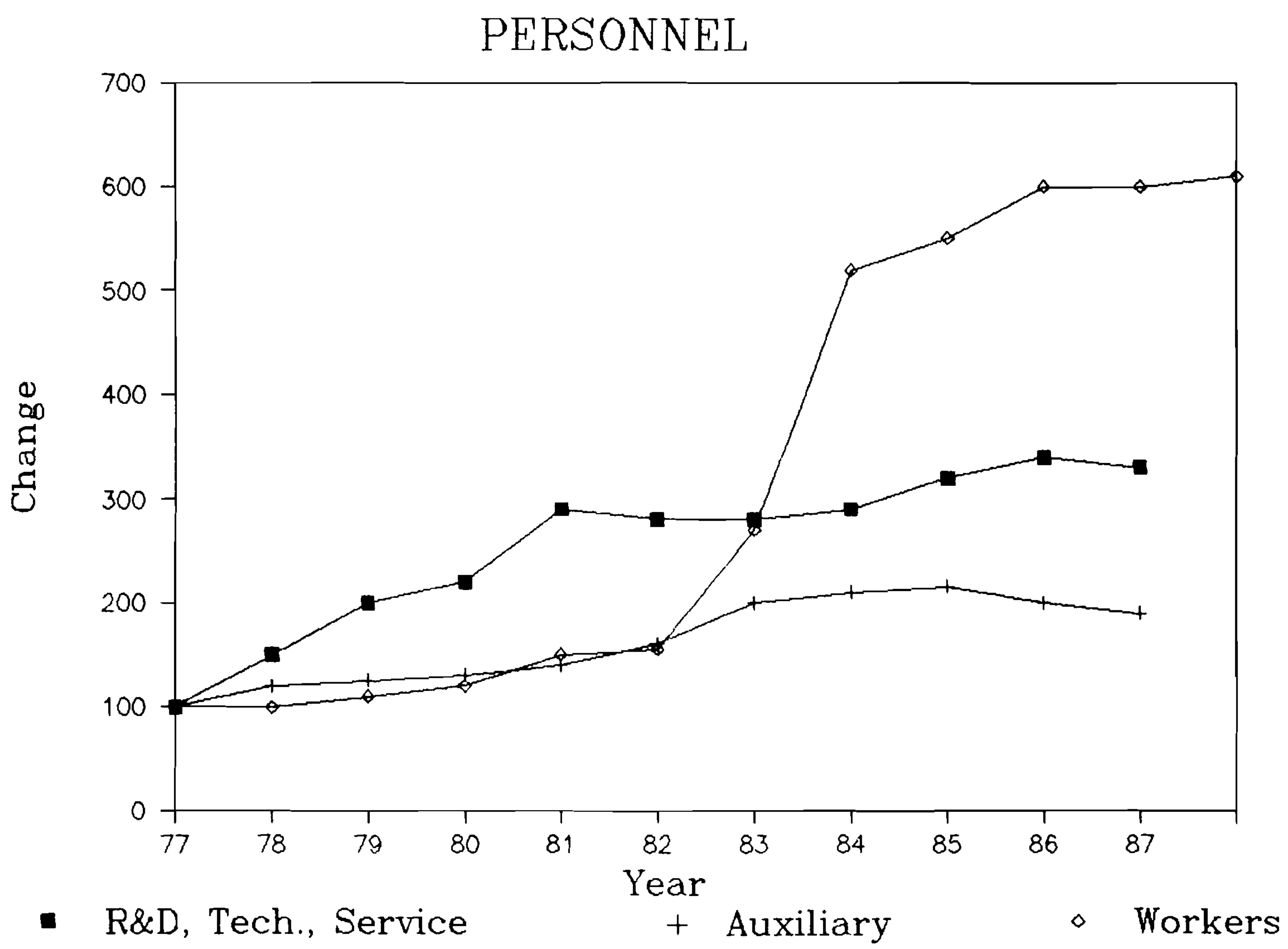

FIGURE 8: DYNAMICS IN PERSONNEL EMPLOYED AT NOVOTEX, 1977–1987