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MANAGEMENT AND TECHNOLOGY LIFE CYCLE: Bulgarian Case Study on the Technology of Counter-pressure Casting

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September 1987
WP-87-088

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
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FORWARD

At IIASA, several researchers have studied and described the cumulative nature of development of technologies and their substitution, using global and macro-economic data. Those processes have their "fine micro-structure" which is interesting and valuable for one country as a whole or for individual companies. Studying this micro-structure can permit us to connect global theory with processes taking place on the micro-level and, based on that, to make recommendations to decision-makers to permit them to select instruments for analyzing and synthesizing their strategy.

Small countries often have limited resources (either natural or financial or even both). However, they always have limited human resources which should be used effectively and purposefully. Today, technological developments even outside the sphere of so-called high-tech are very intensive scientifically and intellectually. This once more increases the necessity for small countries to concentrate their scientific human potential in areas in which they can make break-throughs with high economic efficiency. From this point, positioning technological innovations correctly in the international market and forecasting their competitiveness are very important. A picture of the possible future development of a technological innovation gives the small countries and their companies the opportunity to spot market niches and to develop effective strategies for their fulfillment.

The application of life cycle theory and use of substitution curves as possible management instruments for strategy development on company level is one of the main goals of the research currently being carried out in Bulgaria under the contract with IIASA's "Management of the Technological Life Cycle" (MTL) activity, part of the "Technology-Economy-Society" (TES) program.

The research in Bulgaria is being conducted by the Problem Center "Management of Technological Development" through the Institute for Social Management and has broader goals in the area. These goals are directed towards enhancing instruments for strategic management on company level and methods for accelerating technological development.

The Bulgarian study is directed to three main groups of technologies (irrespective of branch of industry):

a) original Bulgarian technologies with possibilities on international market;

b) new technologies transferred from other countries; and

c) traditional mature technologies.

Structuring the research in this way not only avoids certain drawbacks inherent in research based on particular characteristics of industrial branches (namely the questionable validity of results and lack of transferability of those results to other branches of industry). It also permits researchers to study the dynamics of these technologies and the dynamics of organizational and management characteristics of the companies independent of branch specification, according to the type of technology described and the degree of its development.

In the paper presented, some results of the first stage of the study are discussed. The objects of this first stage are several original Bulgarian technologies. The case study presented here concerns the technology of counter-pressure casting. This original Bulgarian technology is part of a group of technologies based on the method of casting with counter-pressure developed by the Bulgarian Academy of Sciences. The company under study is an interesting integration of a basic research institute, with applied research and production functions.

Preliminary results based only on aluminum casting technology are presented in this paper. This method is also being applied to plastic and steel casting technologies which will be addressed in the second stage of the study.

Variables and indicators through which technology is studied are developed within the MTL activity, but for the purposes of national study have been adapted, increased in number, and developed according to the specific requirements of a centrally planned economy by the Bulgarian national team.

Evka Razvigorova
Principle Investigator
TES-MTL activity

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INTRODUCTION

Scientific and technological progress affects all fields of creative human activities and penetrates into the production sphere through the development of new products and technologies, of new organizational forms and relations of management. Together with the new forms and relations, there appear also complex technological chains which go through the whole national economy of the countries, and in many cases pass their boundaries and influence the development of whole industrial branches in other countries.

The implementation of scientific and technological progress reduces the life cycle of products and technologies, shortens the phases of the reproduction process, and introduces greater dynamics in production relations. In this way, the course of the evolutionary development of economic processes is affected. This makes more complicated the strategic direction of economic processes by means of selection of products and technologies possessing good qualities and providing long-term efficiency for the country and for the producers.

In economic environments where the opportunities for extensive development are limited by the deficiency of raw materials, energy, and human resources, where frequent and unexpected changes in the market condition emerge, where production processes are very complicated from a technical and technological point of view, the role of strategic decisions for planning and coordination is becoming more and more important. These decisions originate from the main goals of the producers -- survival and prosperity, and embrace the main tasks of the development of the business organization: identifying promising and efficient products to be produced in the near future and further ahead, opening markets for new sales, organizing a network of sub-contractors, development and innovation of production facilities, etc. On this basis, the organizations-producers define their strategy for current behavior and for development during the next 5, 10, 15, or more years.

The creation of strategy in business organizations is preceded by an analysis and evaluation of: the technical level of present products and the technologies used for their production, economic characteristics of production, market relations, organizational and management conditions, social activities, and personnel policy. On the basis of these analyses and evaluations and taking into account the decisions of the higher authorities and institutions, the production potential and the strategic goals of the organization are defined, and later alternative strategies are developed according to accepted goals.

Apart from the numerous practical problems related to working out a strategy for the development of a business organization, the main methodological problem is selecting tools for analysis of indicators and alternatives, for comparative evaluations of technical and economic levels, for selecting alternatives, products, technologies, etc. Therefore, a lot of research has been done during recent years in Bulgaria to create the methodological basis of strategic planning and strategic management through development, selection, and field-testing of tools that are suitable for making strategic analyses and evaluations: symbolic models, graphic and analytical forms, matrices and other simple techniques.

This paper presents the results from the first stage of the study "Management and Technology Life Cycle," which is being carried out in the Metals Technology Corporation.

The study has been implemented as part of the activities of the Problem Center on Management of Technological Development at the Institute for Social Management and aims to fulfil the demand in the country for a complex and organized investigation of the problems related to strategic management of technologies. Another reason for undertaking this study was the need to improve the management of technological development in the Bulgarian self-managing business organizations. The results from the study will be presented to IIASA in fulfillment of the contracting obligations of the Problem Center (ISM) and the Metals Technology Corporation to the MTL project within IIASA's research program, "Technology, Economy, and Society."

The paper presents the results from the first stage (See Part I.1.) of the study of technologies from Group A. They are based on the new Bulgarian method for casting with counter-pressure.

The first stage of the study in the Metals Technology Corporation (MTC) was carried out by a working team to provide methodological assistance and summarize the results, consisting of the following persons: From ISM - J. Djarova, Group Leader, and I. Nenov; from MTC - G. Nachev, Group Leader, and T. Tonchev. The following people from the staff of MTC assisted the study as well: G. Gemdjian, P. Rjapov, G. Russev, N. Tzenov, P. Iordanova, E. Toncheva, and E. Todorova. E. Razvigorova, MTL principal investigator, served as consultant.

PART I. METHODOLOGICAL PRINCIPLES AND OBJECT OF INVESTIGATION

1. General Methodological Principles of the Study

The study, "Management and Technology Life Cycle," aims to reveal the regularities of technological development, the relation between technology dynamics and the development of the management system, and as a whole, to define the strategy of the business organization.

In order to reach these final results, the study passes through several stages, differentiated from each other according to their main goals:

* Stage One: Define the present state of the development of the technology and of the management system and for a selected past period. Analyze the problems related with the management of innovations.

* Stage Two: Foresee the future development of the technologies and the requirements to accelerate this development, with recommendations to apply the most suitable organizational strategy, organizational forms, and management methods.

The first stage is directed to accomplish the following objectives:

a) To trace and analyze the life cycle of the technology in question;

b) To define the position of the technology among its competitors;

c) To find out the significance of the technology;

d) To trace back and analyze the organizational forms that existed during the development of the technology.

In order to obtain the results so necessary for the management practice, the studies aimed at solving two main problems: What should the management authorities know about the development of the technology in order to accelerate it and orient it in the right direction? and How can existing theoretical assumptions about the laws of technological development be used in order to improve the system for technology management?

To give management systematic knowledge, it is necessary to study the selected technologies from the moment of their creation to their practical implementation and development. The dynamics of the technology and its characteristics were used as a basis in defining what is general and what is specific in the development of the technology and what were the stages of its development.

To analyze the future improvement of management, the well-known hypothesis that the management system and its elements change depending on the stage of technological development was tested in practice. In this connection, the study was directed to:

1) Analysis of technology dynamics and technology assessment;

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

The analysis of technology dynamics was based on the technology life cycle and the stages in its creation and development. Various indicators are used for the construction of the life cycle. These are mainly economic indicators whose dynamics shows the different phases of the life cycle. The indicators for obtaining the life cycle are selected with a view to the goals of the study, but often the classical curve of the life cycle gives only a most general and incomplete picture of the development of a particular technology. If only the life cycle concept is used, it is not always possible to make detailed analysis of the main characteristics of the innovation process. What is more, when the goal is to reveal the problems in the system of managing the process of technological development, this is even less possible. Therefore, as a basis for analysis of technology dynamics, both the stages of its development and the changes in its main characteristics in time are used.

The final conclusions about the technology dynamics are based on two main characteristics: the life cycle and the stages of the technological innovation process.

The assessment of the level of the technology aims at identifying its state, comparing it with competitive technologies in terms of some main technical characteristics. Through comparative analysis of the main elements of the technology, some conclusions are reached about its present competitiveness and its future prospects. The main aspect in technology assessment is the identification of its significance for the business organization which creates and implements the technology and for other organizations-consumers as well as for the whole national economy. The degree and the directions of its dissemination and multiplication in the country and abroad and of its efficiency indicate both the utmost (or marginal) potential of the technology and its future prospects.

The analysis and evaluation of the management of the innovation process is done in several cross-sections, in accordance with the stages of technology creation and development:

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

* analysis of the economic conditions in which the organizational units perform their activities: financial and credit relations, planning procedures, stimulation, etc.

The results from the second main field of the study are important in order to define the strengths and the weaknesses of the organizational forms and methods at each stage of the technology, to reach conclusions about the improvement of the management system in a time of accelerated technical change.

In line with the general concept of the study, the first stage was completed on the basis of a system of indicators, organized into four main groups (See Appendix 1). The first group aims at describing technology dynamics, and in combination with the indicators from the second group, identifies the main characteristics of the technology as they develop in time and assesses its level, competitiveness, future prospects, and potential. The last two groups identify the present state and the problems of the management system according to the technology dynamics, i.e. the organizational, economic, and management conditions for the development of the technology at each stage.

2. Object of Study

Within the "new technologies" group, the object of investigation is the process of creation and development of the technologies for casting with counter-pressure. The counter-pressure method is an original Bulgarian invention, patented in 33 industrialized countries in Europe, Asia, and America.

The counter-pressure method is a principally new method to produce alloys of non-ferrous metals, products from foamed thermoplastic materials, and steel castings of higher quality. The technologies based on this method possess better technical and economic characteristics than the competitive methods for casting and facilitate the control on the technological process.

As an object of investigation at the stage, the technology for casting with counter-pressure of castings from aluminum alloys, which is one of the main application fields of the method in the country and abroad, was selected. It also made it possible to trace its development longer back in time. A peculiarity of the object of investigation is that presently the innovation process from the idea for a new technology to its implementation in production and transfer to other countries takes place in one business organization, the Metal Technology Corporation.

In the documents setting up this organization, its activities are defined as follows: carrying out fundamental research in the fields of counter-pressure casting methods and on problems related to these methods; applied research and development activities in the field of the counter-pressure casting methods and on problems related to them; production of machines and equipment; production of new metal and non-metal materials, parts, and castings; implementation of the counter-pressure methods in branches of the national economy; sale of licenses and know-how and export of machines, castings, and parts; sales and engineering in the country and abroad; transfer of technologies.

This coincidence between the object of investigation, i.e. the process of creation, development, and transfer of new technologies, with the activities performed by the MTC, makes it possible to concentrate the study only within this corporation and reach a complete agreement between the organization of the study and its goals at the present stage.

PART II. TECHNOLOGY DYNAMICS

The study of technology dynamics was oriented to fulfilling the following tasks:

* To define the duration of the process of creation and development of the technology to the present moment;

* To define the main periods in the process of technology development;

* To compare the dynamics of the technology with that of other similar technologies, types of production, etc.;

* To define the vigorousness of the technology at the present moment;

* To make assessments and conclusions about the state of the technology.

1. Technology Life Cycle

The idea of this part of the study was to use the concept of the product life cycle as a tool for analysis, considering the technology as a product. The technology life cycle in this particular case was built up using various indicators, the most important of which from an analysis point of view being: sales volume (technology transfer); production volume of products using this technology in the country and abroad, and their market share.

The first indicator describes the behavior of the technology as a product for sales as it develops in time, and of its separate elements. Comparing sales of the technology on the market with those of other similar technologies using the life cycle curve gives an idea about the demand for the technology at different points of time and its expected potential. This type of comparison is not sufficiently revealing when the technology is unique. In this case, it is possible to compare the opportunities for sales of the products produced with the technology. The products inevitably come into competition with many other products which serve the same functions, but have been produced through other technologies. Complementing the picture of the technology life cycle with analysis of the market behavior of the products produced with this technology allows better opportunities for assessing the vitality, competitiveness, and future prospects of the technology.

The analysis improves when the behavior of the technology in time is traced and compared for different markets. The most frequent practical difficulties in doing this are due to the incomplete data available to the researchers (producers).

The study illustrates the life cycle of the technology for counter-pressure casting of aluminum alloys, built up with the help of the following indicators: sales volume of the technology (sales of dies and machines), production volume of products produced with this technology in Bulgaria and in other countries, and market share of the products.

1.1. Sales Volume

Sales volume is used to analyze the dynamics of sales during the selected past period in terms of volume, orientation of sales, and types of deliveries. The sales of a technology for counter-pressure casting are considered separately for each of its elements, as each of them can be sold separately. The elements of the technology are: machines for casting with counter-pressure and the die plus technological documentation (know-how). It is necessary to point out that the machine is the chief embodiment of the patent protection of the method. Any other producer can cast with counter-pressure after buying a machine designed on this principle from the only producer in the country and abroad, the MTC. The die and the technological documentation realize the product technology, and each new kind of die bear in itself "know-how." At the same time, the exported machine incorporates the know-how of the method and exports it. Each producer, having bought the machine for counter-pressure casting, can produce products whose first die and technological documentation he has to buy from MTC. He can also develop his own product technologies. The dependence between the organization which owns the discovery and the clients is essential both for the sales of the technology and for the strategy of its development.

The analysis of the production and sales of counter-pressure technologies covers the period from 1968, i.e. from the implementation of the first industrial technology, to the end of 1986.

The data for the past period (See Table 1) show that for the last 10 years the production and sale of machines, although deviating within certain limits, has not grown. There is a tendency to keep the production on a certain level since 1979.

It is not possible to judge about the phase of the technology only from the data about the export of machines (as one element of the technology). This could be possible if the information defined the real opportunities for sales and the closeness to the point of saturation of market demand. In this connection, two limiting factors for the growth of the technology in terms of sales volume were introduced:

* the study and development of the market for the technologies for aluminum alloys casting, and

* the strategy for allocation of production facilities and the different types of machines for counter-pressure casting of aluminum alloys, plastic materials, steel, etc., and the total production capacity of the factory for machines production.

TABLE 1. PRODUCTION AND SALES OF MACHINES

YEARS	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
NUMBER OF UNITS	1	3	3	4	6	10	19	21	24	34	25	5	16	25	25	19	19	17

The opportunities for selling the technology are complemented to a considerable extent by the exports of dies with technological documentation, or the so-called product technologies (See Figure 1). The increased sales of the product technologies only show that the opportunities of the method are not yet exhausted, and it is possible to start large-scale launching at the market. The sharp increase in the sales of the product technologies after 1983 indicates the more intensive utilization of the research potential and deeper penetration into the essence of the method and its opportunities. The changing market of the products influences the dynamics of product innovation in the Metals Technology Corporation, where each new die with corresponding technological documentation is a new product.

1.2. Production Volume of Castings

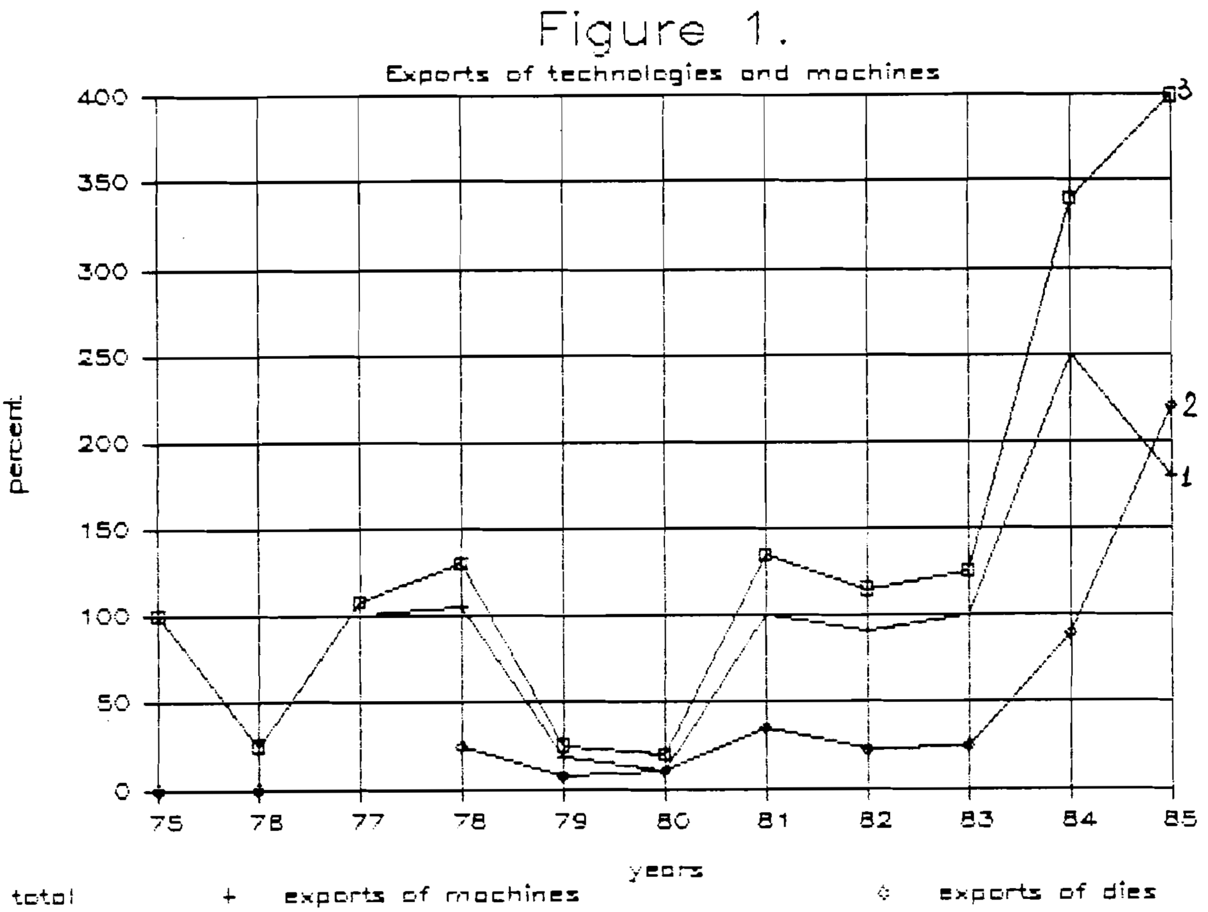
The total quantity of aluminum castings, including such with counter-pressure in Bulgaria has been studied for the past period of time. The following conclusions can be reached on the basis of the data available (See Table 2 and Figure 2):

* The production of aluminum castings with counter-pressure has been growing steadily;

* The growth in the production of castings with counter-pressure is considerably higher compared with the growth of production using the conventional methods;

* The relative share of the aluminum castings with counter-pressure has been growing: from 0.5% in 1970, it reached 18.16% in 1985.

Figure 1



curve 1 - exports of machines

curve 2 - exports of dies and technological documentation

curve 3 - total exports

Table 2

Table 2. Production of Aluminum Casting in the Country

year	Production of a.c. in the country-total		Production of a.c. with counter-pressure		Relative share of the a.c. with counter-pressure
	tons	growth %	tons	growth %	%
1968	5800	-	1	-	0.017
1969	6400	110.30	17	1700.00	0.27
1970	7000	109.40	35	206.00	0.50
1971	7700	110.00	53	151.00	0.68
1972	8500	110.40	110	207.00	1.29
1973	9300	109.40	200	182.00	2.15
1974	10200	109.70	340	170.00	3.33
1975	11200	109.80	410	120.00	3.66
1976	13000	116.10	647	158.00	4.98
1977	12500	96.20	734	113.00	5.87
1978	12500	100.00	1106	151.00	8.85
1979	13000	104.00	1668	151.00	12.83
1980	13500	103.80	2454	147.00	18.18
1981	14000	103.70	2052	84.00	14.66
1982	15000	107.10	2181	106.00	14.54
1983	16500	110.00	2848	131.00	17.26
1984	18000	109.00	3445	121.00	19.14
1985	19000	105.60	3450	100.10	18.16
1986	20000	105.30	4000	116.00	20.00

Figure 2

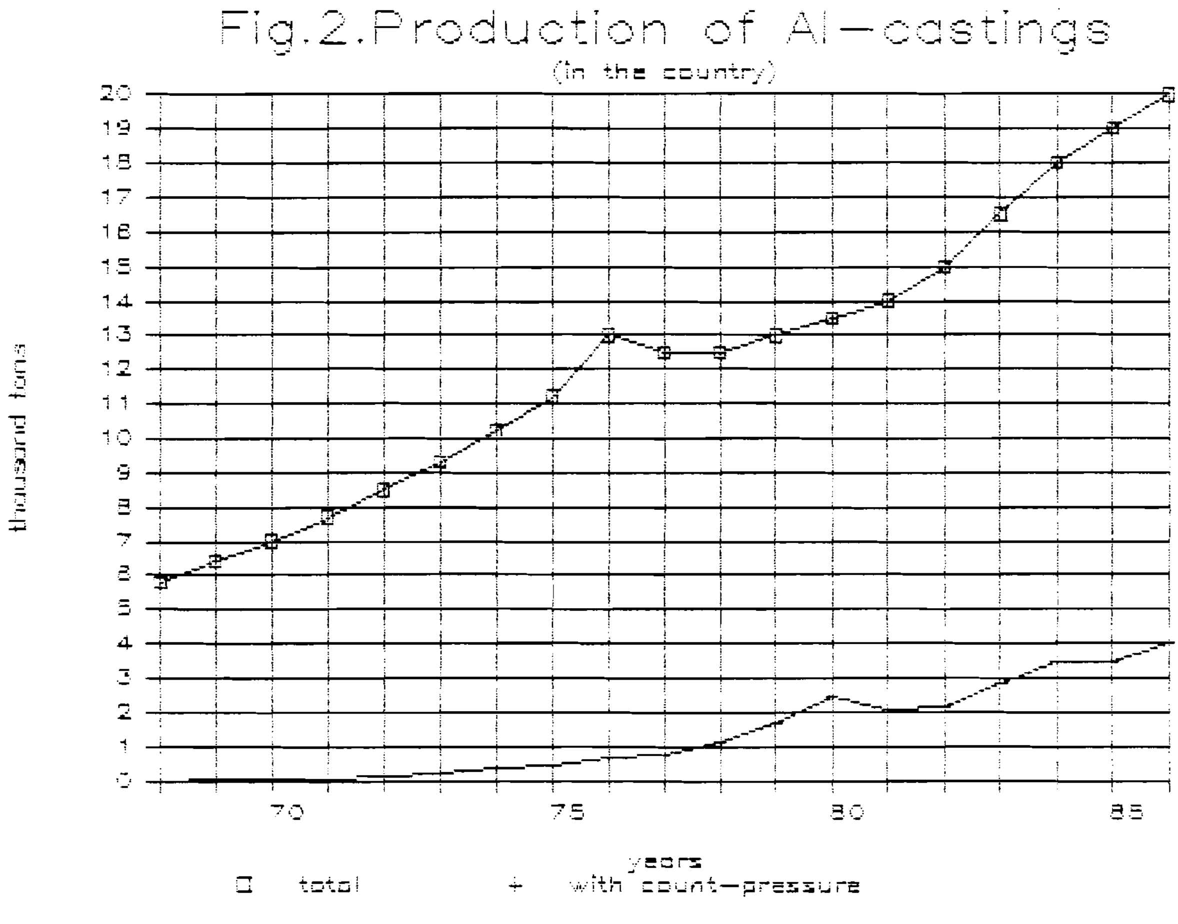


Fig.2.Production of Al-castings
(in the country)
thousand tons
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
70
75
80
85
years
total
with count-pressure

The production of aluminum alloys with counter-pressure in other countries (See Figure 3 and Table 3) was realized by means of the technologies sold by the Metals Technology Corporation. The production in Socialist countries grew from 2,700 tons in 1976 to 26,500 tons in 1985. The relative share of aluminum castings with counter-pressure produced in Socialist countries from the total volume of production outside the country was 93% in 1976, 95% in 1980, and 77% in 1985, due to the increasing share of the castings produced in non-Socialist countries.

The production of aluminum castings with this method is increasing more and more, the growth being bigger in Socialist countries. Besides, it is necessary to make an analysis of the product spectra of aluminum castings using the counter-pressure method. If the variety of aluminum castings is investigated, this will give an idea whether the method is able to diversify the product list, and if so, in which fields. The information required for the above analysis will bring the research back to that stage of the study for a more detailed analysis of the behavior of Al products on the market.

2. Stages in the Development of the Technology

The development of each innovation is a multi-functional process. The successful new technologies require strong cooperation between functional fields like R&D, production, and marketing and a corresponding coordination of line management in the management system. In the conditions of rapid technological development, when the goal is to accelerate innovation processes as a whole, it becomes more and more difficult to differentiate clearly the role of separate functions in the life cycle phases. Therefore, the definition of the life cycle only on the basis of the behavior of economic indicators is not sufficient to explain the dynamics of technologies. The second approach to analyzing technology dynamics is related to distinguishing specific stages in the development of the technology, which may not coincide with the phases of the life cycle. It is convenient to define the stages of technological development by describing the different functions, activities, etc. that have been observed during the periods of transition from the idea to the industrial model, sales, and then to large-scale production. Such stages could be: research, invention, design, development of laboratory and industrial models, planning and preparation of production, marketing, improvement of the technology, exports, etc. Each of these activities has its peculiarities, its own meaning and impact on the development of the technology.

Figure 3

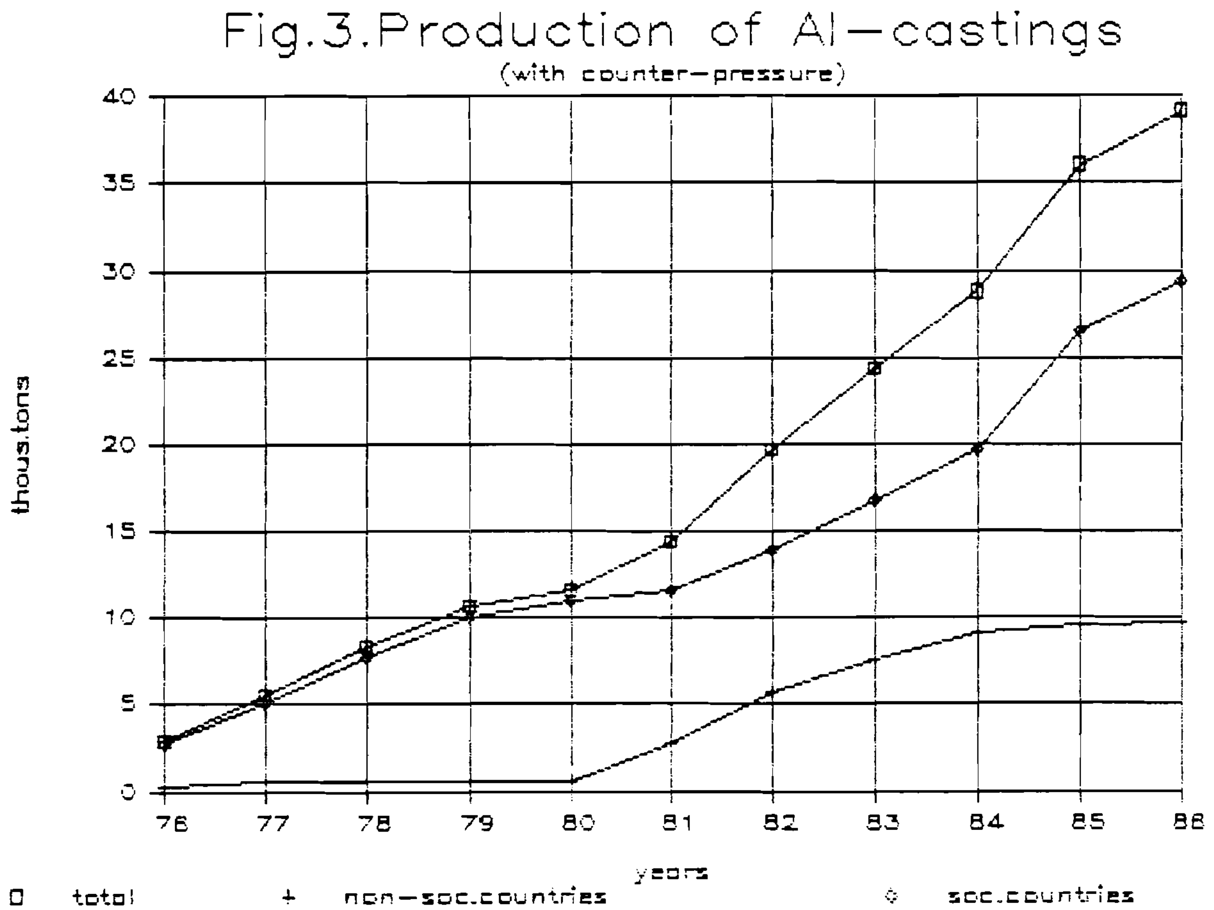


Fig.3.Production of Al—castings
(with counter—pressure)
thous.tons
0
5
10
15
20
25
30
35
40
76
77
78
79
80
81
82
83
84
85
86
years
□ total
+ non—soc.countries
◇ soc.countries

Table 3

Table 3. Production of A.C. with Counter-Pressure in other countries

year	in socialist countries		in non-socialist countries		total	
	tons	growth%	tons	growth %	tons	growth%
1975						
1976	2700		200		2900	
1977	5050	187.00	500	250.00	5550	191.00
1978	7750	153.00	600	120.00	8350	150.00
1979	10050	130.00	600	100.00	10650	128.00
1980	11050	110.00	600	100.00	11650	109.00
1981	11650	105.00	2800	467.00	14450	124.00
1982	13950	120.00	5700	204.00	19650	136.00
1983	16800	120.00	7600	133.00	24400	124.00
1984	19700	117.00	9100	120.00	28800	118.00
1985	26500	135.00	9600	105.00	36100	125.00
1986	29400	111.00	9800	102.00	39200	129.00

The stages in the development of this particular technology are (See Figure 4):

* The idea to use gas in the machines for casting non-ferrous metals and controlling the technological processes in casting which appeared and was developed in one of the units of the Bulgarian Academy of Science. In 1961, this idea was recognized to be an invention and was protected with patents and certificates for authorship in the country and abroad.

* On the basis of the developed principles of using counter-pressure in casting, the first special laboratory machine for casting with counter-pressure was designed in 1963.

* The machine was produced in 1964. The first laboratory tests to cast parts with counter-pressure were made.

* Simultaneously with the production of the laboratory machine began the design of the first industrial machine, which was produced in 1966.

* The experience accumulated from the laboratory tests and the work of the industrial model made it possible to develop and implement in production the first industrial technology within two years (1966-1967). A specific feature of the development of ideas, designs, and technologies (laboratory and industrial) is the overlapping of separate stages. For example, the development of the design and the production of separate, already designed assemblies in the industrial machine began simultaneously with the completion of the laboratory machine. The first industrial technology was developed simultaneously with the production of the machine. Such an overlapping of stages, which is possible only in the presence of very clear concepts, ultimately reduces the time from the idea to its implementation. (In this particular case, the period is at least 2 years.) It is necessary to add to the stages of technology creation the stages of technology development observed from the moment of implementation into production.

3. Development of the Technology

The development of the technology for casting with counter-pressure can be described best through the improvement of its elements: machines through which it is realized; industrial equipment; control of the technological process. During the study, it was discovered that the variety of aluminum alloys used, the qualification of the labor force, and other elements of the technology are not among the main indicators for its development.

Figure 4

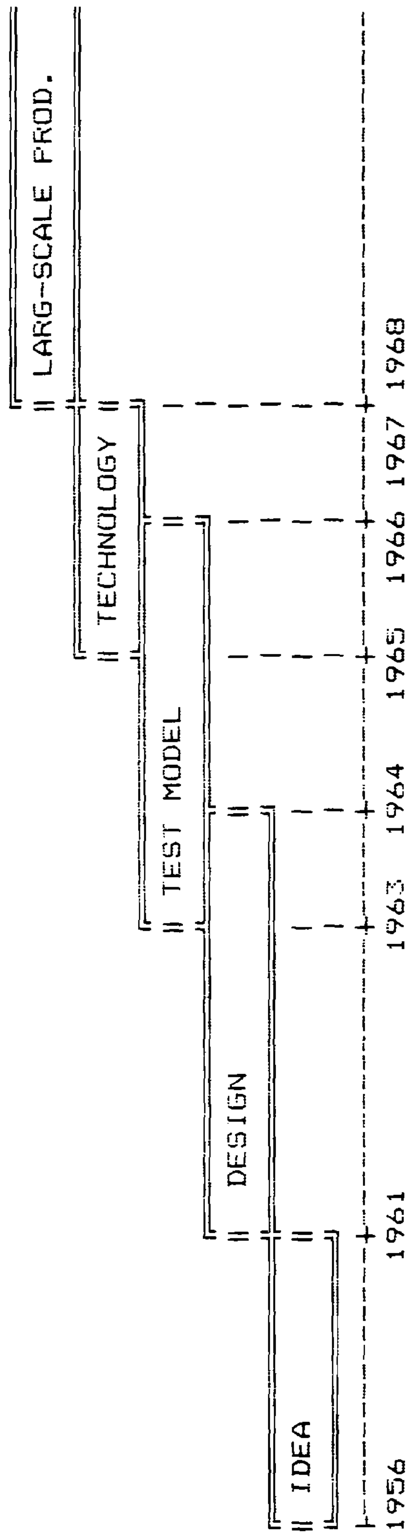


Fig. 4. Stages in the development of the technology

3.1. Renovation of the Counter-Pressure Casting Machines

Renovation of the machines is studied by assessing the constructive and economic innovations with the help of technical and economic indicators. On this basis, conclusions were drawn as to their functional convenience and preferableness.

In 1964, the first specialized machine for casting aluminum alloys with counter-pressure was produced. It applied in practice the main principles of the method. After making the necessary technological tests, the first machine for industrial production was created in 1966. The accumulated experience brought on the creation of a family of machines VP for counter-pressure casting with improved pneumatic and hydraulic systems for control on the technological cycle. Mechanization was introduced in the lifting and hydraulic locking of the intermediate plate (one of the main parts of the machine), and the opening of the machine and its loading with metal was automated. Thus the machine improved its reliability by about 25%,[1] the speed and the precision in adjusting the parameters for casting increased by approximately 30%, manual work in technological operations was reduced by about 15%, the stability of technological processes was improved.

The further development of the design of these machines opens opportunities for using dies with complicated shape and a big number of cores, as well as for using two furnaces. The change of the pouring pipe was also improved. Various kinds of mechanic hands and manipulators were developed for taking the castings away from the machines and placing the sand cores.

Later on, the dimensions of the machine were reduced and optimal dimensions were set. With these machines, it is possible to realize the most complicated and varied product technologies using metal, sand, and sand-and-metal molds. Productivity increased by 28%. Profitability increased by 30% because of the repetition of the technological cycle. Metal consumption was reduced by 12% and energy consumption by 8%. The necessary conditions were created for eliminating the harmful emissions from the technological process. By means of introducing automatic control and improvement in the design, complete safety for the workers was provided.

A new concept for new machines is being developed. They will allow operation of many machines by one worker, using technological modules for full automation of the technological pro-

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[1]Here and further on in the text, the data for the improvement in the technical and economic indicators of the process that was obtained as a result of developing the design and the technology have been averaged.

cess, casting and crystallization under pressure, removal of the castings, transportation, and removal of the pouring system. Micro-processor control on the technological process and flexible production systems are being introduced.

3.2. Improvement of the Dies

The changes and improvements in the dies, their influence on the quality and the type of products, the duration of the technological cycle, the consumption of materials, etc. have been analyzed. Being one of the main elements of the technology, the dies were improved in several directions.

In 1981, the technology for casting with reduced "dead heads" (i.e. compressed air is introduced into the mould to perform the same function) was introduced in some of the castings. This reduces the costs of the further mechanical processing and economizes metal.

A pouring system with an overflow was introduced in 1983. The strengths of this system are that crystallization takes place faster which reduces the casting cycle by up to 20% and increases profitability by about 18%.

In the same year, separate cooling of the die was introduced in the casting of various kinds of parts. Forced cooling of the metal cores was implemented, making the process controllable in terms of time and temperature depending on the technological requirements. This also cuts down the casting cycle by about 15% and increases the productivity of the technology by about 8%.

The design of some dies was improved by means of eliminating the heaters, which reduces the consumption of energy.

By means of introducing a pouring system with more than one pouring pipe, it became possible to cast large-dimensional products with complicated shapes.

3.3. Improvement of the Control of the Technological Process

On the basis of the above mentioned innovations (in the machines, dies, and conditions), the control operations, control systems, and the regulation of the technological parameters were analyzed and assessed. Conclusions were drawn about the stability of the technological process, its flexibility in the production of different configurations and large products.

The control of the processes in counter-pressure casting has been developing in parallel with the innovation and improvement of the machines and technologies. The accumulated experience and knowledge about the developing physical and chemical processes created conditions for developing a package of mathematical models of the behavior of the "machine-metal-product" system and for passing from manual, semi-automated, and automated control to control by microprocessors.

The automation of the technological process is closely related to the improvement of the design of separate meetings and blocks in the machines and dies. The latter are related with the ideas and models about technological control. This makes the improvement of the technology a continuous, iterative process. Simultaneously with control automation of the technological process and in close relation to it, was the "out-of-machine" control. All major elements of the production process (transportation of the fluid metal and of the casting and removal of the pouring system) are mechanized and automated.

The latest concepts about the directions for the development of the machine, external automation and mechanization show that in principle it is possible to create modules of machines an equipment for counter-pressure casting, making them part of more flexible production systems. The degree of automation of the separate modules will be defined mainly on the basis of economic and social considerations.

The tendencies towards automation of the production of machines, instrumental equipment, and casting technologies with the counter-pressure method developed along global tendencies, because this type of production is essentially conventional. Generally speaking, these tendencies are:

* Application of CAD systems; (preliminary calculations show that after implementing the system, the time for developing the technological documentation will be reduced 5 to 6 times.)

* Application of digital control machines for metal processing;

* Increased share of the digital control machines;

* Introduction of flexible production control systems in the mechanical shops of the plants producing machines and instrumental equipment;

* Introduction of systems for current control on the production process in the mechanical and assembly shops.

4. Conclusions about the Dynamics of the Technology and its Main Characteristics

The studies in the field of technology development, using the life cycle concept, are a starting point which, together with further empirical testing of other objects, can enrich the life cycle theory in the field of technologies. The conclusion up till now is that the life cycle of one technology is determined to a large extent by its internal opportunity to be improved. The improvement potential also indicated the vitality of the technology. This potential takes into account the changes in the elements of the technology, the diversification of its products, and its possibilities to penetrate into other branches and types of production. When the rate of raising the technical level of one technology is decreasing, just as when its efficiency is decreasing, its future prospects are also reduced. In this case, the "saturation level" on the life cycle curve can be extended only when there is not yet other sufficiently competitive technology on the market, and the demand is either the same or is increasing.

Four main stages exist in the development of the separate elements of the technology: machines, dies, control system for the technological process (See Table 4).

The first stage is realized on machines with electrical conductor control and manual regulation of the process parameters. The casting is done in metal molds. The technology allows casting of parts with simple shape, without flaws, and with one separation plane.

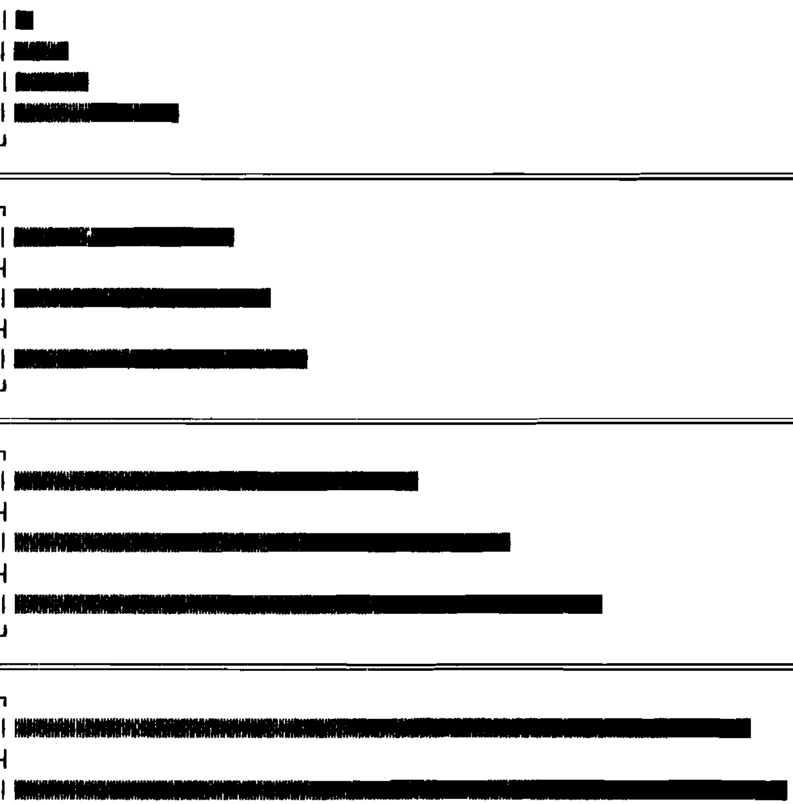
The diversification of the technology applications and the growth in sales during the period 1968-1978 are due mainly to the relatively improved quality of the castings obtained by means of the new technology. During this period, the technology for counter-pressure casting was applied for casting hydraulic elements and cases of hydraulic cranks, for parts in the radio industry, radio-navigation equipment, and pressing machines.

The second stage in the development of the technology covers the improvements in the hydraulic and pneumatic systems of the machines, the introduction of metal-and-sand molds, and the improved control. Cranks for heavy diesel engines started to be produced, also hydro-dynamic transmissions for diesel engines with complex sand cores, cases for electro-engines and electric hoists, parts for engines for high-voltage and computer equipment, complex castings for Vankel engines, etc.

The introduction since 1981 of technologies with reduced "dead heads" in the casting and the improved line-matics of the die allowed the implementation of more efficient technologies for casting wheels for cars, a great variety of parts for agricultural machines, pistons and cranks for diesel engines. Large wheels for belt transmissions were introduced, without mechanical processing of the canals.

Table 4. Stages in the development of the Technology

stage	technology improvement: machine	technology improvement: die	technology improvement: control	product	year	Production of alluminium castings with counter-pressure (thousand tons) 5 10 15 20 25 30 35 40 45
I	industrial model	metal	electrical-contactor and manual	-hydralic elements -parts for the radio industry, -parts for pressing machines	1968 .... 1975 1976 1977 1978	
II	pneumatics, hydraul	metal and sand	semi-automatic control	-crank cases	1979	
				-hydraulic trasm.	1980	
	2 furn.	reduc.riser		-wheels for cars	1981	
III	kinematics of the die	separated and forsed cooling, moveble cores	automatic control	pistons for motors	1982	
				pts f agricult.mach	1983	
				wheels for truks	1984	
IV		sand	micro-processor	motor cylynders	1985	
					1986	



Starting in 1985, micro-processor control was introduced, which allows for controlling a larger number of technological parameters. The technology of casting wheels for heavy trucks and buses is being implemented, as well as a number of technologies for production of important parts of the brake system. The possibility to use sand molds increases the efficiency of the process and allows production of such complicated castings like cylinder heads of engines with internal combustion.

The analysis of the past period shows that after the technology for casting with counter-pressure appeared, the improvement of its elements has been oriented toward increasing its competitiveness by means of improving the properties and reducing the metal consumption of the products, increasing machines reliability, improving working conditions, protecting the environment, and extending the application fields. At the same time, there has been permanent growth in the production of aluminum castings.

The general conclusions with regard to the technology dynamics are:

1. The technology is in a growth phases, defined by means of two criteria: a) export opportunities, competitiveness and unfulfilled market demand, and b) opportunities for improvement.

2. The technology has been in the process of creation for about 10 years, has been implemented for another 10 years, and has been developed and transferred abroad for another 10 years. The stages of its development: idea, design, test model, industrial technology, and large-scale production follow each other and partly overlap in time, which shows accelerated technological development. On the other hand, the 10 years of orientation primarily to the domestic market slowed down its transfer to other countries, in spite of the patents.

3. Throughout its development, the technology has been improving in all its elements, which has preserved its competitiveness on a relatively high level, and has been the main reason for increasing the volume of production of Al castings in Bulgaria and abroad.

PART III. TECHNOLOGY ASSESSMENT

The assessment of the technology level is one of the bases for analyzing the strategy of the organization at the present moment, and for defining the strategic directions for technological development. It must give an answer to the question, "What is the position of the technology among its competitors, and in what direction should it develop?" The level of the technology is determined not only by means of comparative analysis with other similar technologies along some technical characteristics, but also by its significance for the country and for the business organization. The function and the significance of the technology are important indicators which influence essentially the characteristics of the management system and the decisions about technology development.

1. Comparison with Competitive Technologies

The comparison is made for the separate elements of the technology in order to assess the strengths and weaknesses in relation to competitive technologies. On this basis, the competitiveness of the technology is defined and the capacity of the producer to keep it on a high technical level.

The method of counter-pressure casting is performed by means of a machine which can be produced only by the MTC because of its uniqueness and patent protection. Normally, each machine is provided with a die for producing a certain product, and a technological documentation. Both the machine and the first die contain in them the know-how of the producer. Each next (duplicating) die can be produced by the consumer or by other specialized producers. The MTC does not aim at developing production facilities for producing duplicating dies for its clients, because this does not fall within the object of its activities and because of the high competition of the traditional producers in the country and abroad.

Since the die transfers the ready product technology to the client, and this technology is created only by the MTC, the area of competition and further penetration into the market is realized first of all through the machines for counter-pressure casting and the new product technologies. This determines to a large extent the marketing strategy of the MTC as a creator and a producer of the technology.

The technology for casting with counter-pressure is a fundamentally new technology for producing castings of non-ferrous alloys, foamed thermo-plastic materials and steel. In the field of Al alloys, it competes with the following technologies: casting under high pressure, die-casting, casting under low pressure, vacuum casting, autoclave casting.

When the opportunities of the technology to be used for the production of a greater variety of products were studied, the conclusion was drawn that the counter-pressure technology can practically be applied for all types of castings, but it is most efficient in the production of castings with high physical and mechanical characteristics, density, and reliability. The main peculiarity of this technology which makes it different from others is that the pressure of the technological gas is used both for transportation of the fluid material to the mould and for control of the crystallization process. The specific features of the technology allow structuring its advantages in terms of three criteria: quality of the end product, efficiency of the production process, and possibilities for extending the product range. The studies led to the following results:

1. The quality of Al castings has improved: the strength is 20 to 30% higher than in the case of die casting, and plasticity has increased 2 to 3 times; the precise regulation of the speed in filling the die allows an improved appearance of the casting.

2. The efficiency from the production of Al alloys castings has increased: the economy of metal is up to 30%, resulting from the reduced pouring systems and dead heads and from the reduce weight of the castings because of the opportunity to obtain equal properties with thinner walls of the castings; reduction of the mechanic residue of castings; improved working conditions and less pollution; possibilities to fully automate the process.

3. The product range has been enlarged. It is possible to produce castings with complex shapes in metal, sand, and metal-and-sand molds, avoiding the danger of destroying the sand molds and cores; possibilities for casting alloys with volatile components and using protective gases as technological gas.

The technology allows shortening the technological cycle by means of eliminating thermal processing, which bring a reduction in the production cost of the products of about 25%.

The comparative analysis[2] was done in terms of 40 indicators which are further specifications of the 3 criteria mentioned above. The comparison, made by means of an experts' procedure and tested again in the course of the present study, led to the following conclusions:

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[2]The study on the position of the technology for casting with counter-pressure among competitive technologies was based also on the comparative analysis carried out by a working team under the supervision of the authors of the technology.

* The technology for casting with counter-pressure exceeds at this moment all other competitive methods;

* Potentially the biggest competitors are the methods of casting under low pressure and die casting;

It is reasonable at the present moment to compare the counter-pressure technology with the technology for casting under low pressure. However, the potential opportunities of the vacuum and autoclave casting should also be taken into consideration when the strategy for technology development has been worked out.

2. Significance of the Technology

The whole cycle of reproduction in the field of counter-pressure casting, from fundamental and applied research to the production and sale of technologies and products, is closed within the Metals Technology Corporation. Three types of completely different products are produced at the different stages of the reproduction process:

* Research product, which is a result from the fundamental studies in the field of casting with counter-pressure. It keeps the scientific potential of the method on a high level;

* Design and technological product (various machines for counter-pressure casting, product technologies based on the method);

* products produced by means of the technology.

The object of our study is the development of the technological product since the products obtained by means of the counter-pressure technologies have a considerable share in the production program of the MTC, and it is with them that the organization takes part in the national balances of the country. This determines the high significance of both the technology and its products for the MTC and for branches of the national economy.

2.1. Significance for the Organization

The Metals Technology Corporation was set up in order to secure the research and technological development of the methods of casting with counter-pressure and to extend the application of the technologies in the branches of the national economy. The introduction of counter-pressure casting into the national economy is made through developing product technologies and producing products with them. Production facilities for this method exist only with the MTC system. With the extension of the product range in the production units of the corporation, more and more products obtained through casting with counter-pressure are produced in branches of the national economy.

The product structure of the corporation includes both products produced with the method of counter-pressure and products produced with the conventional technologies in the field of the ferrous industry, metal casting, and machine-building. Figure 5 shows the profit from the sale of products by MTC during different years. The data show that the profit share from the sale of the products produced with counter-pressure is growing as compared with that from the sale of "conventional" products. The structure of the profit from the counter-pressure products consists of the profit from the products and profit from the machines and the dies.

The Metals Technology Corporation sells on the domestic market mainly products produced with the technology of counter-pressure and on the international market, especially during the last several years, technologies. By means of exporting technologies, the experience gained in the process of research and development is used most efficiently, and the return on the investment is increased. The corporation uses various forms in its efforts to penetrate the market. It creates joint ventures or purely Bulgarian branches abroad; it maintains contacts with leading firms for improving the machine design, joint sales, technology transfer, etc. In all these forms, the technologies for casting with counter-pressure are a considerable share of the MTC participation in this cooperation.

The fundamentally new technologies for casting with counter-pressure create new work stations, completely different from those to be found traditionally in casting. The improved safety of the machines and their mechanization makes the work more attractive. The highly automated machines have created a new profession, that of operator on a machine for casting with counter-pressure. The higher quality of the machines for casting with counter-pressure requires the introduction of highly productive metal-cutting machines and digitally controlled machines.

All this also determines the social significance of the technologies for casting with counter-pressure for the workers in the MTC.

2.2. Significance for the National Economy

The counter-pressure method and the machines, product technologies, and materials developed on this basis, raise the national prestige first of all because of their high level and uniqueness.

Figure 5

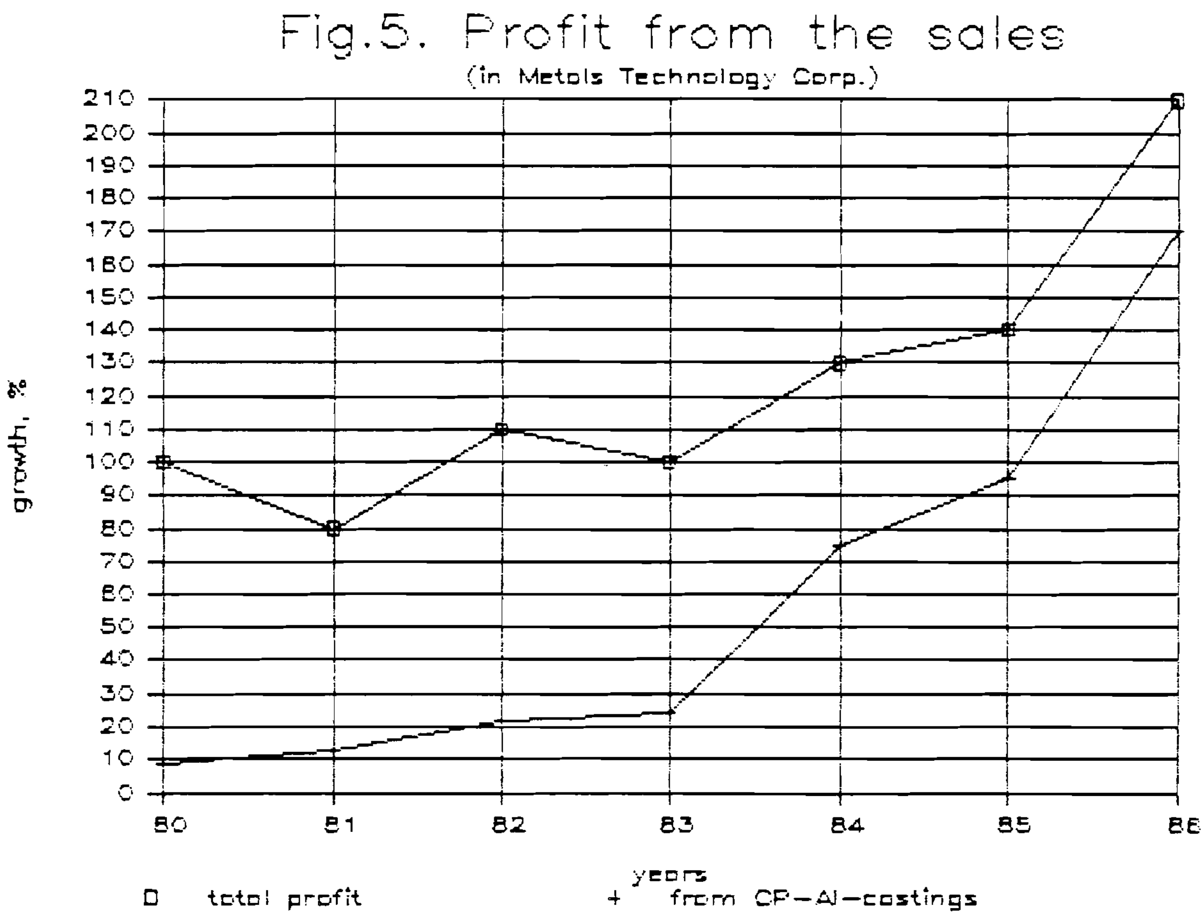


Fig.5. Profit from the sales
(in Metals Technology Corp.)
growth, %
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
80
81
82
83
84
85
86
years
□ total profit
+ from CP-Al-castings

The method allowed its diffustion in the following branches of the national economy: machine-building, electronics, electrotechnology, agriculture, chemical industry, construction, and energy production.

This multiplication was possible by means of using the materials and products to design products produced in other business organizations. The counter-pressure technologies replace the conventional casting methods, improve the physical characteristics of the parts and their reliability, etc. The application of the counter-pressure technologies improves the technological development of the branches of the national economy.

The application fields of the method and the forms of its realization as well as the impact on the branches of the national economy are shown in Table 5. The table also shows the number of inventions in the respective fields.

The application of the method abroad is protected with more than 300 patents and certificated for authorship in 33 countries.

Not least in importance is the social significance of the counter-pressure technologies for the national economy. The future creation of production facilities for producing products with this technology in other business organizations and branches of the national economy will create highly automated work stations with much better working conditions. The ecological parameters of the working environment will improve. These technologies will, in turn, pose serious requirements in the field of training workers and specialists.

The potential opportunities of the counter-pressure technologies, along with those of other strategic technologies, create conditions for technological and product innovation of the national economy.

3. Conclusions about the Level and the Significance of the Technology

The following general conclusions regarding the technology and its significance as well as the needs for further development and improvement have been reached:

1. The technology is unique and competes successfully with the technologies for casting under low pressure (its main competitor at the moment) in terms of three criteria: quality of the product, production efficiency, and opportunity to extend the product range.

TABLE 5. APPLICATION FIELDS OF THE METHOD

N	FIELD & FORM OF REALIZATION	BRANCHES	IMPACT
1	2	3	4
1	Production of castings of non-ferrous metals and alloys Inventions - 58	Machine-building Electronics Electro-Tech. Metallurgy Agriculture	-Products of higher quality -Economy of Al alloys: 10 th.t/yr until 1990.
2	Production of products from foamed thermoplastic Inventions - 15	Machine-Building Electronics Agriculture Chemicals Construction	-Economy of plastic (5-5th t/yr from longer use of products) -Substitution of high quality steels and non-ferrous metals
3	Production of nitric steels and products Inventions - 173	Machine-Building Metallurgy Construction Mining Agriculture	-Development of new, more efficient materials -Substitution of imported alloyed steels -Functional improvement of products
4	Equipment for research and control of production processes, special tech. equipment Inventions - 173	Machine-Building Electronics Electro-Tech. Construction Metallurgy	-Increased research efficiency -Increased production efficiency -Better quality -Higher productivity

2. It is necessary to direct attention to the vacuum and autoclave casting, which are also potentially competitive.

3. The counter-pressure casting machine, as an important element of the technology, has better characteristics than that for casting under low pressure, but the quality of its performance must improve. Additional value engineering is needed in order to define the goals in raising the quality of the machine.

4. It is necessary to carry out a large study on the competitive position of the technology in different markets and to outline the strategic directions of technological development.

5. The technology is very important for the national economy because of its multiplication effect in different industrial branches. Its impact is felt in such advanced fields as the development of new materials, economy of expensive raw materials, increasing productivity and product quality.

6. The technology demonstrates a high level of innovation. As a basic innovation, it gives birth to a number of derived innovations in many fields. More than 300 inventions have been made so far. The innovative potential of the technology shows its future prospects.

7. The study of the significance of the technology for the organization defines the Metals Technology Corporation first of all as a technology-oriented producer. This determines and should continue to determine the organization strategy.

PART IV. ORGANIZATIONAL FORMS

1. Dynamics of the Organizational Forms

In studying the management system, the research, management, and organizational structures are analyzed from the moment the technology appeared as a scientific achievement to the present time. Comparison is made between the organizational forms and structures during the main stages in the development of the technology, in order to determine the degree of their suitability and to explain facts, tendencies, and results that have speeded up or slowed down the technological development of the relevant business organizations and research units.

Each organizational form is analyzed with regard to:

* its purpose and object of activities;
* its subordination and relations with superior or subordinate authorities and organizations;
* its size and number of employees;
* its opportunities for influencing its own development (strategic planning);
* its sources for promoting (financing) technological development, etc.

The organizational forms and their main activities are separated according to the stages of the technology development. They are list in Table 6.

1.1. Research Unit

The idea about the fundamentally new method for casting with counter-pressure appeared at the Bulgarian Academy of Science. In order to create conditions for developing the idea, a department "Metals and Machine-Building" was created (1961) within the Technical Institute of the BAS. It later developed into an independent unit with the Technical Division of the BAS. This unit developed the design of the first laboratory and industrial machines. This is where the first technology for casting with counter-pressure was developed.

During this period, the unit consisted of 27 persons (scientific and technical personnel) working in several laboratories: "casting and crystallization," chemical, etc.

The unit did research in the field of castings for the car industry, hydraulics, pneumatics, electro-technology, etc. At

TABLE 6. ORGANIZATIONAL FORMS

STAGES	YEARS	ORGANIZATIONAL FORMS	ACTIVITIES	REMARKS
Idea of method's principles	1956-1961	BAS-Department of Technology	Fundamental Research	
Design	1961-1964	--	--	
Laboratory Prototype	1963-1966	BAS-Institute of Metals Technology	--	
Test Model	1963-1966	BAS-Institute of Metals Technology	Research for Implementation & Applied Studies	
Industrial Technology	1965-1967	BAS-Institute of Metals Technology	--	
Production	1968-1973	BAS-Institute of Metal Technology, BO "Casting Equipment"	Implementation, Production	BO "Casting Equipment" has 1 research institute, 2 machine-building plants and 1 foundry
	1973-1986	Metals Technology Corporation	Fundamental & applied research, production activities, engineering, foreign trade	MTC: IMT/ BAS, institutes for applied research, production & engineering enterprises, foreign trade organization

the same time, its studies were oriented to create unique equipment for research purposes: vertical pneumatic equipment for casting with counter-pressure, gravitation system for casting with counter-pressure, autoclave for casting and crystallization, a machine for casting in a controllable atmosphere, etc.

During the period 1961-1966, the unit grew to 100 persons and was transformed into a central laboratory for research in the following fields: casting Al alloys, developing new alloys, casting steel alloys, physics of metals, developing alloyed metals with gas constituent, developing non-metal materials, designing machines.

As a result of these studies, in 1967, the first family of vertical pneumatic machines for casting with counter-pressure, the test model, was created.

The development of the unit during this period corresponded to the long-term objectives and plans of the BAS, i.e. to finance fundamental research in this field. The strategic decisions at this stage were developed in the unit and were agreed to by the management of the Bulgarian Academy of Science.

1.2. Institute of Metals Technology

In 1967, the Institute of Metals Technology was created based on the central laboratory. The institute had highly qualified scientists and specialists in several scientific fields, a laboratory for testing materials and an information center.

The production facilities for industrial application of the method consisted of a machine-building plant ("Ilinden"), another plant for dies and other technological equipment ("Original"), and a foundry within the business organization "Casting Equipment," which was created in 1968 under the Ministry of Machine-Building (See Figure 6). During the same year, in order to carry out efficiently the fundamental research for applying the counter-pressure method in industrial technologies, the Research Institute in Casting was set up within the business organization "Casting Equipment." The joint research of the BAS institute and the "Casting Equipment" organization developed the first industrial technology for casting with counter-pressure. During this period, the development of the fundamental research in the IMT was controlled by the BAS management and was financed from the state budget. The applied research was concentrated in the Research Institute in Casting. They were based on the fundamental studies done at the IMT and were directed to developing machines with new design and of various product technologies. The applied activities in the RIC were financed from the funds of "Casting Equipment" and from contracts with external organizations, including the IMT.

Figure 6

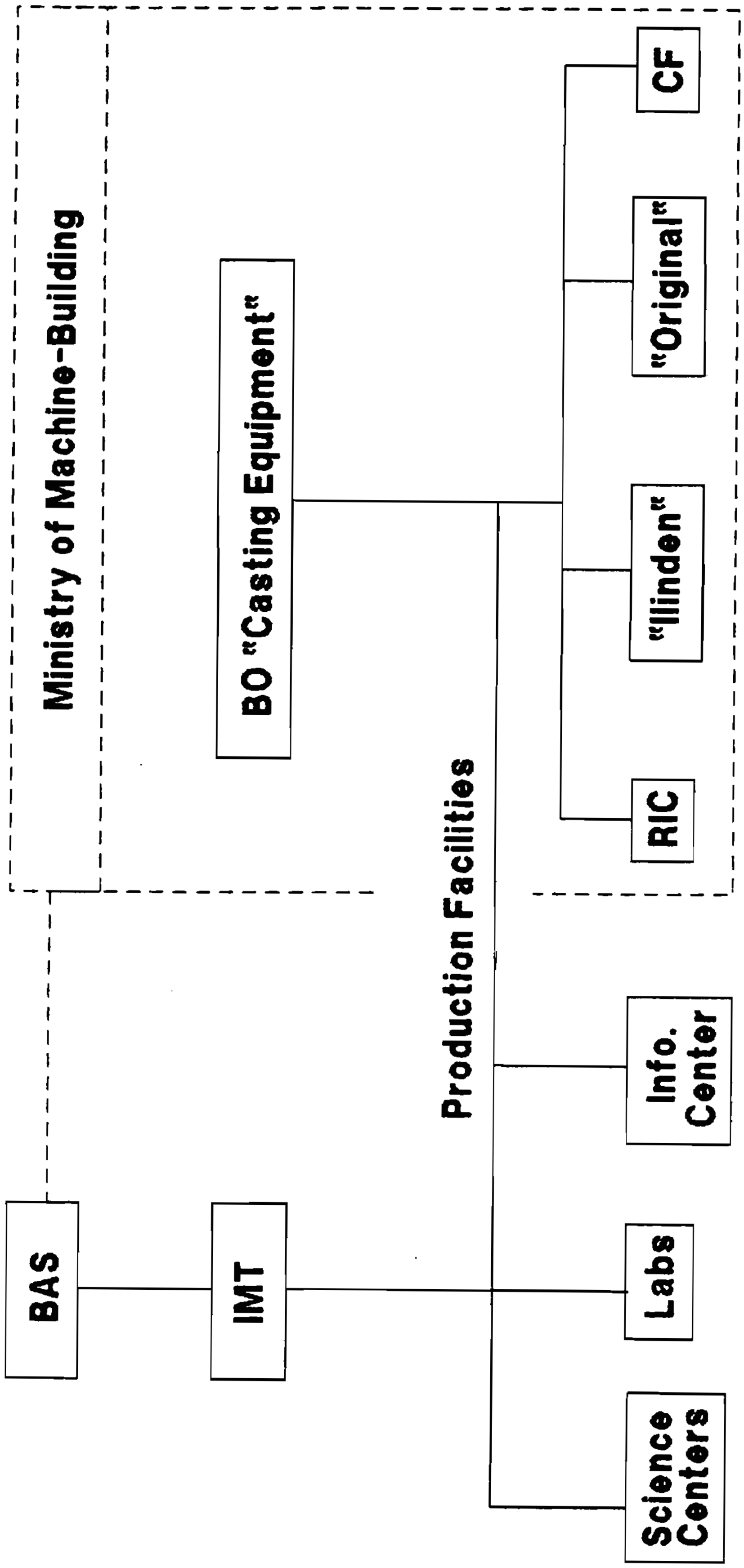


Figure 6 Organizational Chart, 1968-1973

In spite of the different subordination of the IMT and "Casting Equipment," the transfer of fundamental achievements connected with the counter-pressure method was realized through coordinated decisions of the two units. This was reflected in their plans, agreed to respectively by BAS and the Ministry of Machine-Building. At the same time, the research promotion of the specialist from the RIC was planned and handled by the IMT (BAS).

During this period, there was industrial production of machines for casting with counter-pressure, dies, and Al castings, which indicates that the new method was starting to be applied in practice. At this stage, there was not yet a general strategy on the level of BAS and the machine-building branch about the development of the fundamental and applied research and multiplication of the results in the national economy as well as their transfer abroad.

This organizational structure did not provide the necessary conditions for a quick transfer of the results from fundamental research into industrial production. This is due first of all to the different subordination of the unit for fundamental research and the production units, which created:

* lack of coordination of research plans, R&D plans and production plans;

* difficulties in the field of investment;

* difficulties in the concentration of resources for solving the main strategic goal to create the necessary production facilities for scientific and applied research with the methods of casting with counter-pressure;

* insufficient economic links between scientific and economic interests along the chain fundamental research-applied research-production.

1.3. The Metals Technology Corporation

The MTC was set up in 1973 in order to: carry out fundamental research in the field of the methods for casting with counter-pressure and on problems related with these methods; carry out applied studies and R&D in the field of counter-pressure casting methods and on related problems; produce machines and equipment; develop new metal and non-metal materials, parts, and castings; implement the counter-pressure method in branches of the national economy; sell licenses and know-how, export machines, castings and products; perform engineering and sales activities in Bulgaria and other countries; transfer technologies, etc. (See Figure 7).

Figure 7

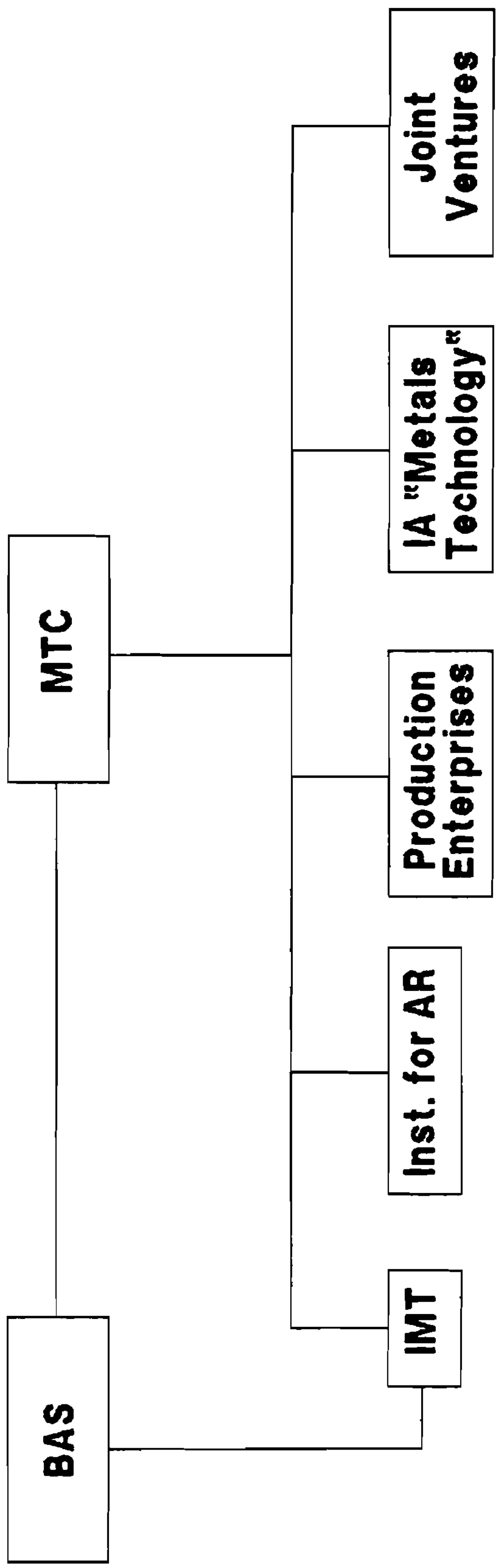


Figure 7 Organizational Chart, 1973-1987

The corporation is directly subordinated to the Council of Ministers in Bulgaria in order to make it possible to multiply the effect from applying the method in branches of the national economy. The resources for the development of the corporation, including those for foreign trade, are provided by the state planning authorities.

To implement the marketing policy of the corporation, a Foreign Trade Direction was created. It sells machines, materials, and products produced with the counter-pressure casting method, product technologies, and know-how.

The corporation at first consisted of IMT, RIC and a factory for producing machines, dies and Al castings. The IMT has preserved its methodological subordination to BAS which finances its activities and provides scientific management.

In 1982, when it became possible to create production units to produce products obtained with the counter-pressure casting method in the country and abroad, the MTC started engineering activities and created for this purpose a specialized enterprise "Techmet."

R&D units were created in the production enterprises in order to enhance the application of the method as quickly as possible in a large number of product groups. Thus, a direct relation between production and research was created and the cycle "research-implementation" shortened.

To speed up the implementation of the results from the method in branches of the national economy, the MTC used various forms of association with other business organizations: joint laboratories for scientific and applied research on new materials and designs, joint enterprises in the country for production of products (plastic packing materials, steel products, etc.), joint ventures with foreign firms (the Setef factory in France).

The new organizational form creates conditions for organized development of the fundamental and applied research and of the production and transfer of technologies, and makes it possible to define the strategic policy of the corporation. The latter is related to developing fundamentally new machines, equipment, and products in branches of the national economy and applying the materials and the technologies. In this way, by developing its strategic decisions, the MTC implements the national policy in the field of counter-pressure casting.

It follows, therefore, that only after the creation of the Metals Technology Corporation was it possible to create real conditions for business organizations in Bulgaria to work out and implement strategic decisions about their own development: distribution of resources, financial and material; introduction of a goal-oriented organization; direct relations with the international market; orienting research.

The activities in the corporation are financed from the following sources:

* fundamental research at the IMT: from the state budget;

* R&D activities: from the funds of the corporation and from contracts with external organizations;

* foreign trade activities: from the funds of the corporation;

* production and engineering activities are self-financing.

From its establishment until the present time, the Metals Technology Corporation, as an organization for fundamental and applied research and production of technologies, products and materials using the methods of casting with counter-pressure, has been placed on different levels in the structures for management of the national economy. During 1976-1980, the corporation belonged to the Committee of Casting and Plastic Processing of Metals, and one part of the factories and institutes were transferred to other organizations. From 1980 to 1986, the corporation has been directly subordinate to the Ministry of Machine-Building. It was during this period that its composition and object of activities were finally defined. Since 1986, in connection with the main task of the corporation to transfer technologies for casting with counter-pressure into branches of the national economy, it has been transformed into a technological center bearing the same name and with the same structure and activities. Since 1987, the Metals Technology Corporation is a member of the Association "Investment Machine-Building" where the organizations are technologically linked. Under this structure, the independence of the organization is preserved, and those strategic decisions which go beyond the object of activities of the corporation are made at the association level.

2. Conclusions about the Organizational Forms and the Organizational Strategy

The analysis of the organizational forms in connection with the stages of the technology leads to the following conclusions:

1. At the different stages of the development of the technology, different organizational forms existed. Until the stage of large-scale production (at the development stages), the organizational form was the classical form of management of fundamental research, a research unit. During the development stages, the organizational forms corresponded to the

degree of technology implementation and to its role in the market.

2. The organizational forms have been more dynamic in the stages after the technology was implemented in production and had established itself in the market as well as until the time when the producer worked out his strategy. In the growth period of the technology after 1973, the organizational form was relatively stable, only its structural elements were developing.

3. The specific features of the organizational forms in the different stages of technological development explain to a certain extent the slow transfer of the technology to other countries. Goal-oriented foreign trade activities started after 1973, i.e. 10 years after the development of the laboratory and industrial models.

4. There is a tendency to improve the organizational forms in order to achieve a better coordination within the cycle research-implementation and to reduce the time of the cycle. In this sense, the last form overcomes the weaknesses related to the different subordination of the unit for fundamental research and of the production enterprise. The organizational form which unites science and production, as experience has shown, assists in a speedy improvement of the technology and its practical implementation.

With regard to the organization's strategy, it is possible to formulate several basic conclusions, originating from the analysis of the past development and the present condition of the technology:

* The strategic decisions for implementing the principle of casting with counter-pressure have been realized in the frame of the research unit at the Bulgarian Academy of Science. That is why from 1968-1978, i.e. the period of transition to the growth stage, the priority was to create production facilities for large-scale production. This was done mainly in the "Casting Equipment" organization and the MTC in machine-building.

* Since 1978, the strategy has given priority to the task of penetrating into the existing markets with new product technologies. It is possible to implement this strategy only if there is an organizational form which connects the scientific and production units and in which marketing plays an important role. At this stage, it is reasonable to preserve the strategy directed to produce machines and new products containing a great deal of know-how as well as to transfer them within the country and abroad.

CONCLUDING REMARKS

In studying the dynamics of counter-pressure casting technology, the results show the following (See Figure 8):

* Considered within the framework of Bulgaria, the technology is in a transitional phase of saturation having reached about 20% of the total production of aluminum castings, this share being restricted by the capacity of the domestic market.

* As far as the international market is concerned, judgements have been made to the effect that the technology is in a phase of growth.

The difference in the state of the technology and its dynamics between the domestic and the international markets are determined by the importance of one of the factors of technological development: the size of the country.

As far as the considered technology is concerned, the difference between the time of its appearance on the domestic market and on the international market is 7 years. In the course of these 7 years, nearly 40 to 50 products have been produced and introduced in many industries, machines and tools have been perfected, some scientific and practical experience has been accumulated, specialists have been trained, capacities have been created, etc.

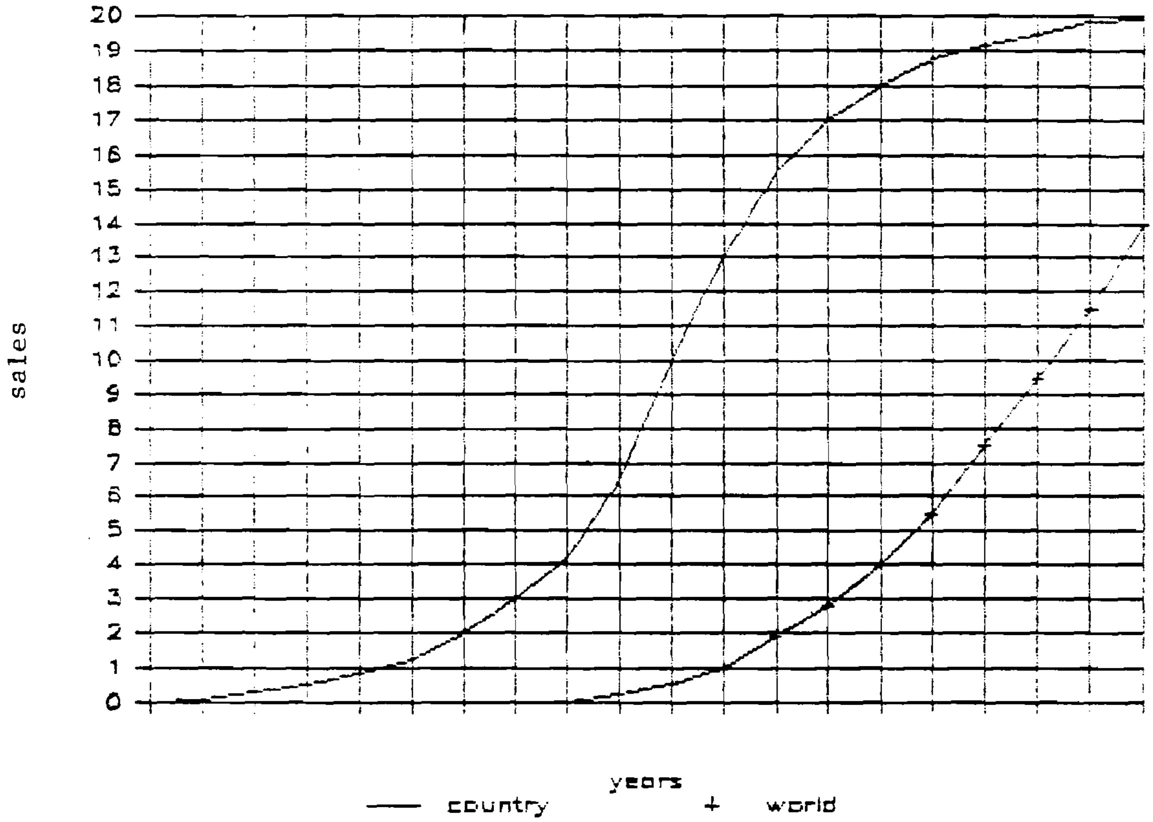
When the first sales were made abroad, aluminum castings made according to the new technology had a share on the domestic market of 10% of all aluminum castings produced in the country.

The delay in entering the international market leads to a delay in realizing profits from the technology implementation; the risk of a competing technology appearing on the market is also greater.

The technology dynamics on the two curves as shown in Figure 8 can be considered typical for some small-size countries. In the beginning of its growth phase, every new technology needs a field of application to prove its efficiency and future prospects. In its initial phase, it is improved on the basis of consumer feedback. At this stage the producer prefers to enter the home market. But the domestic market of a small-size country has a limited capacity and limited possibilities to disseminate the new technology. Therefore, even though it is necessary in many cases, the new technology should enter the international market with as short a delay as possible.

In this connection, it is necessary that a small country should approach new original technologies by priority and provide

Figure 8


20
19
18
17
16
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14
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12
11
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9
8
7
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5
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3
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1
0
sales
years
country
+ world

incentives for their development. The innovator-organization should concentrate resources purposefully not only for research, but also for developing infrastructure and for marketing. In this sense, the strategic management of this type of technology could inevitably be based on analyses and forecasts of technology dynamics.

The life cycle is a tool which can assist in judging the development of a new technology, its state in the cycle phases, and its position among competitors. This method, along with the other methods for analysis, serves in strategic decision-making. To create conditions to accelerate technological development, it is necessary to understand the various organizational forms of management appropriate to the various phases of technological development. The match between the process of technology development and its accompanying system of management creates a favorable environment for promoting technological innovation.

APPENDIX 1.

INDICATORS OF THE STUDY

GROUP A. Indicators for Analyzing Technology Dynamics[a]

Characteristics	Description	Output
1. Technological Life Cycle[a]	* Defined by several indicators: production volume, sales volume, market share, profit investments, production costs, etc. from the time of technology introduction through to production.	* Technology life cycle phases divided into 4: introduction, growth, maturity and recession.
2. Technological Development Stages	* Defined by differentiating functions in time; research, discovery, invention, design, development, prototype, trading, production development, production & marketing planning, tooling & market preparation, production, sale.	* Duration of each stage * Gap between stages * Overlap of stages
3. Life Cycle of Products, produced by the studied technology[a]	* Defined by several indicators: production volume, sales volume, market share, profit, investments, production costs, etc.	* Product life cycle phases.
4. Technology Innovativeness	* Distinguishing the principal changes in technology used and improvements (modifications) of technology. Identification of two kinds of technology innovativeness: 1) new technologies defined based on the changed principle of functioning; 2) improved technologies defined based on improved technology functions.	* Number of technology substitutions * % of principal new technologies and of improved technologies * Rate of technology innovativeness = time/-(new technologies + improved technology)

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[a]The technological and product life cycles are built using the same indicators, but the technological life cycle is based on the indicators' performance of entire production, starting with the point of introduction until the present time, independently of product changes during this period. The product life cycle is connected only with the concrete product or group of products.

5. Product Innovativeness & Quality	* Examining two kinds of products, produced by studied technology: 1) new products and 2) improved products.	* % of new products/-year * % of new products/-technology's lifetime * % of improved products/year * % of improved products/technology's lifetime * Number of different products produced by the technology
	* Levels of product estimated as a deviation from standard.	* % bad quality products * Deviation from standard, scrap
6. Innovativeness of Technological Equipment	* Examining the age and changes in used technological equipment.	* Average age of equipment * % of equipment changes/technology's lifetime.
7. Changes in Raw Materials Used	* Examining changes with respect to quality, quantity and type of raw materials used in a given technological process.	* % of changes/technology's lifetime.
8. Dependence between Technological and Product Innovativeness	* Defining the time gap between implementation of new technology and production of new products which occur as a result of implemented new technology.	* Time period * % of new products arising from new technology or products.
9. Characteristics of R&D	* Amount of R&D investment * R&D investment by type of innovation * Source of R&D investment.	* % of total investment * % of R&D investment for new product or process & improved product or process.

GROUP B. Features of the Technology Process

1. Type of Technologies Used		* Name, kind.
2. Significance of the Technology for the Organization	* Defined based on production volume using this technology as well as the volume of the outcome (profit) from these products.	* % of producing these products/total production volume * % of outcome/total outcome.
3. Source of the New Technology	* External, internal * License, know-how, R&D activities, etc.	* % of external/internal sources * % of different sources.
4. Type of Manufacturing		* Single prices/small lots/large lots/mass production.
5. Technology Competitiveness	* Defined compared to other technologies on the market.	* Market share, dynamics * Export of technology & of produced products.
6. Automation Level of Production	* Using CAD, CAM, CIM, robots.	* Ratio between CAD, CAM, CIM, robots used.
7. Relative Position of the Technology		* Rate of patents.

GROUP C. Characteristics of Managing the Technological Innovation Process

GROUP C.1. Organizational Characteristics

1. Type & Changes in Production Units		* Hierarchy * Organizational levels.
2. Type of Organizational Structure	* Identifying present & past organizational structures used during the different stages of technology development.	* Succession of different organizational structures: informal, centralized & functional, decentralized, life-staff and project groups (product or process), matrix of teams.

3. Special Structural Forms	* Special structural forms connected with technological innovations.	* Description of these special structural forms.
4. Scale of Management	* Defined by the number of administrative staff.	* Administrative staff as a % of total employees.
5. Organization of Strategic Management with respect to Technological Development	* Estimating the independence of strategic management from external decisions * Role of strategic decisions compared to operational ones	* Body creating strategic policy * Ratio between external & internal strategic decisions * Segregation of strategic & operational management
	* Distribution of responsibilities in the strategic decision-making process.	* % of full-time employees * Description of the organization, affiliation * Description of correspondence between organizational levels & strategic decisions.
6. Environmental Analysis Units		* Organization, affiliation, % of full-time employees.
7. Consultants		* Background, affiliation, number, role (driving force, teaching).
8. Committees/Teams		* Subject, organization, affiliation.

GROUP C.2. Managerial and Social Characteristics

1. Methods for Planning	* Examining the methods for planning mainly in 3 directions: 1) connected with the sources of the methods defined as external & internal sources; 2) connected with the flexibility of used methods, depending on circumstances; 3) level of standardized methods for planning.	* Ratio between external & internal planning procedures * Level of flexibility of the used methods * Ratio between standardized & non-standardized.

2. Methods for Strategic Planning	* Description of the kinds of methods used for strategic planning distinguished as traditional forecasting & planning methods (i.e. extrapolating past trends into the future, optimizational methods, etc.), new methods of scenarios & portfolios (experts' scenarios, morphological approaches, cross-impact approaches, others).	* Description of the methods.
3. Methods for Decision-Making	* Based on managerial intuition & experience, standard procedures available, quantitative & qualitative approaches, modern procedures.	* Description of the methods used.
4. Information Data Base Support for Management Decision-Making	* Distribution & description of the data base available among the functional organizational levels * Examining the level of automation of the information data base used.	* % of the information data base distribution by organizational functions * % of the information data base computerized * Description of the main kinds of information data base used, particularly new information technologies.
5. Orientation of Managerial Functions	* Description of management functions from the point of view of their orientation to: marketing problems (i.e. market planning & organization; supply, service, quality problems; market segmentation); production problems (i.e. planning & organization, production design, production documentation, tooling, pre-production prototypes, raw materials planning, relations with suppliers, production R&D, structure of labor force, control); & technological problems (R&D, documentation, implementation, improvements, transfer of technology).	* Number of departments oriented to: market, production, technology * % of administrative staff by functional orientations.

6. Patterns of Decision-Making	* Managerial autocracy model, systematic bureaucracy model, adoptive planning model, political expediency model, others.	* Description & % of managerial models used.
7. Manager & Management Style	* Structure by position	* President, Chairman, Directors of: R&D, R&D Unit Manager, Technological Development, Economics, Marketing, etc.
	* Qualification	* Education background by specialty
	* Experience	* Career pattern (years)
	* Length of service	* Years at the company
	* Age	
	* Span of control	* Direct and/or indirect
	* Responsibility for implementing and/or developing new technologies	
	* Signing authority for R&D budget.	* Either in %or in actual amount of money.
8. Individual Skills	* Training for new technology	* Months, weeks, hours per person for workers * Months, weeks per person for engineers, technologists
	* Rotation of personnel (R&D & production, etc.)	* As % of rotated persons
	* Personal creativity	* Average number of suggestions per year by personnel categories
	* Employee participation in the decision-making process	* % of decision made with employee participation
	* Types of stimulation systems used, estimation of their effect, budget for these systems	* Description of the different types of stimulation systems used * % of the final effect
	* Special systems and/or approaches for training, for improving qualifications, for stimulating creativity	* Description of systems * Qualitative estimation of systems' effectiveness * % of persons involved with these systems
	* Loyalty.	* Average length of service with company.

GROUP D. Economic Characteristics

1. Profitability		* Growth rate
2. Costs		* Reduction rate
3. Export Effectiveness		* % of export/volume of production * Profitability * Return on export investments.
4. R&D Effectiveness		* Return on R&D investments.
5. Funds Distribution	* Distribution of organizational funds among R&D, production & marketing activities.	* Ratio between the different uses of funds.
6. Labor Performance	* Labor productivity * Working conditions.	* As % * % of manual work * % of automated work * % of polluted working places * % of highly protected work places * % of investment for protection of employees to total investment.