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Tonchev, T., Djarova, J. and Nenov, I.

IIASA Working Paper

WP-89-044

July 1989

WORKING PAPER

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FOREWORD

This paper presents the second part of the case study developed at the Metals Technology Company, in Bulgaria, which created and is applying the new original Bulgarian technology of casting by counter-pressure. After an investigation of the technology life cycle in the first part, the second part of the study concentrates on the inter-relation between technology and product life cycles. Selected product areas were investigated, and the product life cycle was applied in analyzing the product structure of aluminum casting and different product technologies. Reasons for some instances of reduced competitiveness of these technologies leading to lost market positions in certain product areas were also investigated.

The case study demonstrates the applicability of technology and product life cycles as management tools useful in connection with new original technologies, developed in small countries. As a tool, the life cycles can be used to find market niches and strengthen company strategy.

This paper, therefore, is a continuation of the IIASA working paper WP-87-088, "Management and Technology Life Cycle: Bulgarian Case Study on the Technology of Counter-pressure Casting" by J. Djarova, G. Nachev, I. Nenov, and T. Tonchev. The two together describe the entire case study.

F. Schmidt-Bleek
Program Leader
Technology, Economy & Society

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INTRODUCTION

The report presents the results from the second stage of the study "Management and Technology Life Cycle (The Case of the Counter-pressure Casting of Aluminum Alloys)." The theoretical applied study "Management and Technology Life Cycle" fulfills the need for improving the management system of technological development in companies. Through the study results, the Problem Center for Management of Technological Development at the Institute of Social Management and the Metals Technology Company fulfil their contractual obligations to the MTC project of IIASA's TES program.

The study is directed to revealing the laws of technological development, the relation between technology dynamics and product structure, the development of the management system and definition of the development strategy of the business organization.

During the first stage, carried out at the Metals Technology Company, the following studies were made with regard to the technology for counter-pressure casting of aluminum alloys:

* analysis of the technology's life cycle;
* assessment of its competitiveness;
* definition of its significance;
* delineation of the organization forms in existence during the technology's development over the period 1968-1986.

The fulfillment of the tasks of the study's first stage led to the formulation of some conclusions about the life cycle and the viability of the technology. These conclusions are important for the transition to the second stage of the study and to defining its goals. Here are the main objectives:

* The counter-pressure technology in the development (or growth) phase, defined on the basis of the opportunities for exporting the technology due to its high competitiveness, opportunities for its improvement, and unfulfilled market demands.

* Throughout the stages of its development, the technology has been constantly improving all its elements. This has kept it highly competitive and has made it possible to increase the volume of production of aluminum alloys in Bulgaria and in other countries.

* The technology is unique and has competed successfully with the conventional technologies with the quality of the product, the efficiency of production, and the opportunities for enlarging the product range.

* It is necessary to make an extensive study of the competitiveness of the technology in different market segments and

for different groups of products, and to make more precise evaluations about the strategic fields of technological development.

* The technology is very important for the national economy because of the multiple effect of its application in various industries. Its effect is manifested in such leading fields of technological development such as the creation of new high-quality materials, economic use of raw materials, and increased productivity and quality.

* The technology is on a very high innovation level. Over 300 inventions have been made based upon it. The innovation potential of the technology indicates its advanced nature and its viability.

* The study on the significance of the technology for the organization has shown that the Metal Technology Corporation is a technology-oriented producer. This determines and should continue to determine in future the development strategy of both the technology and the organization.

It is important for the Metals Technology Company to investigate the laws of development of the product "technology." Because of the large variety of products which can be produced with the counter-pressure casting technology and because of the great number of product niches which have not been studied so far, the behavior of this product is to a large extent unpredictable. The investment, technological and product strategy of the organization depends on the depth with which the law of technology development will be made clear.

The second stage of the study was carried out in the Metals Technology Company by a working team. Prof. E. Razvigorova, MTC principal investigator, served as consultant on methodological issues.

1. OBJECT AND METHODOLOGICAL PRINCIPLES OF THE STUDY

1.1. Object of the Study

The object of the study during the second stage will again be the technology of counter-pressure casting of aluminum alloys, and the analysis will be oriented to products. A specific feature of the products produced with this technology is that both the machine for counter-pressure casting and the products are novelties. The product technologies are realized through the die, and each new type of die bears "know-how," while the product is innovation. Each producer who possesses the counter-pressure machine can produce products, but in order to do that, he must buy the first

die and the technological documentation from the Metals Technology Company.

The studies of the technology's life cycle led to the conclusion that the possibilities for selling the technology depend considerably on the export of dies and technological documentation, i.e. the product technologies. The increased sales of the product technologies shows that the opportunities for applying the counter-pressure method have not yet been exhausted and allow a further market increase. The sharp increase in the sales of product technologies after 1983 indicates the more intensive use of the company's research potential and the deeper penetration into the essence of the method and its opportunities. Since 1980, the realization of the counter-pressure casting technology for aluminum alloys has been growing, judging by the export of product technologies.

1.2. General Methodological Principles

During the first stage, the technology was analyzed as a product, and its development was defined as a whole for the machine, die and know-how. This was done on the basis of the methodological assumption that the retrospective development of each technology can be traced by studying several general indicators of the technology elements. In order to define its future development, however, it is necessary to use predicting assessments for a large number of product groups in which production can be implemented by means of the same technology. The results from the first stage showed that the products (or bearers of novelties) related with the counter-pressure casting method are of great important for the analysis and assessment of technological development.

In addition, the relative share of the future production of some product groups with the new technology and that of the production with competitive technologies are also indicative. The first stage of the study showed that it is not possible to make final assessments of technological development without analyzing the product fields and markets in which the technology is penetrating with its new and improved products.

On the basis of the above data, it is possible to construct a forecasting curve of the counter-pressure casting technology and its dynamics during different life cycle phases.

Therefore, the viability of each technology should be determined from the point of view of the life cycles of the produced products and those which are in a process of implementation.

The life cycle of products is affected strongly by many market factors which determine the demand for these products and the length and stability of the life cycle. These factors deter-

mine also the distribution of the products among the various market segments.

The counter-pressure casting technology is realized on the market through the products which are produced with this technology. Therefore, the potential of the technology depends on the qualities and behavior of the market for these products. To have a technology which is advanced and competitive is not enough. If the technology is directed to product markets which have little potential, this will affect the potential and efficiency of the technology itself.

The analysis of the relation "technology-product" is necessary in order to justify the development strategy of the business organization in which the product and technology structure play a determining role. Therefore, the goals of the second stage of the study are to analyze the product structure of the castings from aluminum alloys produced with counter-pressure and to give recommendations for introducing the method in the product fields.

Analyzing the product structure of aluminum alloys, it will be possible to find the product fields in which the counter-pressure casting technology has penetrated. In order to do this, two classification criteria were selected: degree of penetration in the different sub-branches and degree of realization of the main advantages of the method. Using the above criteria, the study will determine the representative product range for the technology of counter-pressure casting of aluminum alloys.

The life cycles of the products and the factors which affect them are studied in the framework of the representative product range, the pre-conditions for creating the company product strategy are also analyzed.

2. ANALYSIS OF PRODUCT FIELDS

2.1. Classification of Product Technologies

The production of casting from aluminum alloys using 101 technologies for counter-pressure casting in the Metals Technology Company was traced for the period 1975-1986. The data for the total consumption of aluminum castings in the country and the production of castings with counter-pressure technology are shown in Figure 1. The volume of the castings produced with the CPC (counter-pressure casting) technology grew from 3.66% in 1975 to 21% in 1987. The studies show that in 1990 the CPC technology castings will be 27.5% of the total consumption of aluminum castings in the country.

Table 1 contains data for the production of aluminum casting with the 101 product technologies developed and implemented after 1975. In 1976, these technologies were used to produce 48% of

all castings obtained by means of the counter-pressure method. In 1986, this share grew to 69%. This shows that the sample studies exceed 50% of all CPC technology castings.

The first criterion for classification of the studied product technologies is the degree of penetration in the different sub-branches. CPC technology have been introduced most widely in transport machine-building, where 42 technologies were implemented (46.6% of the number of the studied technologies) and 7,837.1 tons of castings have been produced (i.e., 45.2% of the entire quantity of CPC technology castings in the product fields under review). The company started the production of bearing wheels for vehicles, crank cases, casings and bodies for diesel engines, hydro-dynamic transmissions, etc.

Of the castings, 38.3% or 6,679 tons were produced for the needs of electronics and electro-technology with 30 technologies (27.7% of the total number of technologies). The counter-pressure method is used for casting the bodies and hoods of electrical engines, crank cases for electrical equipment, a large number of part for computers and memories.

In general machine-building (telpher-building, textile machine-building, food industry machine-building, etc.), 29 products (28.7% of the studied technologies) were introduced, and the total production for the period is 2,987 tons (or 16.5%).

The conclusion is that CPC technologies were introduced in different sectors of the national economy during the last 10-12 years, but the rate was not very high.

The second criterion for assessing the product technologies is the degree of realization of the main advantages of the method for counter-pressure casting: high physical mechanical properties, economy of metal, opportunities to control the crystallization process during casting, etc.

From the 101 technologies included in the study, of special interest are 22 technologies in six product fields:

* castings of parts for hydro-dynamic transmissions,
* castings of crank cases for electrical equipment,
* castings of bearing wheels,
* castings of automobile wheels,
* castings of station wagon wheels,
* castings of crank cases for diesel engines and heavy reduction gears.

The products made with these technologies are more competitive than the corresponding products produced with the conventional technologies in the country and abroad. Therefore, the application of the counter-pressure technologies eliminate the

necessity for import or the production of products with other less efficient methods. This can be illustrated by the introduction of the technology for casting crank cases for diesel engines (see Figure 3). The first castings with CPC technology appeared in 1978, and at first fulfilled 20% of the domestic demand for engines. The remaining 80% were produced through die-casting. From 1978 to 1981, the share of crank cases produced with counter-pressure increased, and after 1981, 100% of the needed crank cases were produced with this technology. A similar picture was observed in other product fields.

The assessment of the remaining 79 technologies from the point of view of this criterion showed that the majority of them were not developed on the basis of the most typical for the counter-pressure method product fields. These are either technologies which make it possible to produce products with considerably higher consumption qualities than those required by the consumer, i.e. he has to pay for higher quality than necessary or technologies which can be replaced with conventional methods, thus reducing production costs. There are several typical examples: the castings from aluminum alloys, produced through counter-pressure from 1976 to 1984 for cam presses P-63 of 1985 were replaced again with steel castings because of their lower price; two types of castings for textile machines, because of the low requirements for strength and air-tightness can be produced more efficiently on high-pressure machines, etc.

Eight of the studied parts can be produced through die-casting. The lower quality of the castings does not influence the quality of the final product and is fully compensated by their lower costs. Besides, their conventional production with minimum capital investment can be organized by the consumer.

2.2. Life Cycle of the Typical Aluminum Alloys Products

The production of castings in the five selected product fields (with the exception of heavy truck wheels in which the technology is in a process of implementation) is shown in Figure 4. In all product fields, after 1981, there was a tendency to grow. The marketing studies in these product fields show that the demand for aluminum castings will be increasing during the next years and will follow the production growth of the products in which they are used. Therefore, at the present time, the counter-pressure technology has no competitor in these product fields, and it is possible to expect that the production of aluminum castings with this technology will increase.

The product strategy of the Metals Technology Company is directly affected by the demand in the respective product field and the presence of more efficient competitive technologies. To illustrate this, the castings for hydro-dynamic transmissions were analyzed. Figure 5 shows the life cycle of the parts for hydro-

dynamic transmissions produced with the counter-pressure technology. The hydro-dynamic transmission is an assembly which appears in the different types of trucks. The production of hydro-dynamic transmissions is carried out with a license technology. In the beginning, mechanically processed castings of the three main parts: pump wheel, directing gear, and turbine wheel, were imported. The imported castings were produced with the conventional technology for die-casting.

In order to stop the imports of these products, the Metals Technology Company developed in 1978-1980, technologies for their production with counter-pressure, using the opportunities of the counter-pressure technology for casting in metal-sand dies. The castings obtained fulfil all requirements related to the design of the hydro-dynamic transmission, possess better physical mechanical qualities, are smoother, and more economically efficient than the conventional castings.

Another reason for the introduction of these castings in the Metals Technology Company, besides the eliminated need for import from Western countries, is the need existing at that time for using the production capacity of the plant for aluminum castings (PAC).

The increased production of the three parts was caused by the growth of production of hydro-dynamic transmissions in the country, and the Metals Technology Company has to gradually fulfil the needs for castings for the transmissions.

In 1980, the regular production of the directing gear began. The unfulfilled demand for this part and for the other two parts related to the production of hydro-dynamic transmissions was fulfilled through importing.

Before 1981, about 80% of the total demand for parts for hydro-dynamic transmissions was fulfilled with the production of PAC, and the remaining quantities were imported.

Starting from 1982, the PAC has been providing the entire quantity of pump wheels and turbine wheels necessary for the transmissions. In the same year, the directing gear started to be produced locally with a new, more efficient license technology, currently being used by the consumer. In 1987, this technology started to be applied to the production of turbine wheels. Only 8% of the necessary quantities will be produced with the counter-pressure technology. From 1988, the production of this part will be entirely with the new technology. The fulfillment of the demand for parts for hydro-dynamic transmissions produced with the different technologies is shown in Figures 6 to 8.

The production of parts for hydro-dynamic transmissions is a field in which the advantages of the technology for counter-pres-

sure casting in mass production are fully utilized. This is especially true for the more powerful and larger transmissions. At the present moment, the technology has no competitors in this field.

The experience accumulated from the application of the technology in the production of parts for transmissions in the Metals Technology Company and the high competitiveness of the technology have provided opportunities to enter the international market. There are several versions of the strategy for market penetration:

* enlarging the production facilities for counter-pressure casting, increasing the accompanying products, and sales of the ready product;

* sales of the machine with technology and know-how;

* combined sales of ready products and technologies, etc.

The selection of one or more of these strategies depends on a number of factors and will be studied during the second stage of the study.

Figure 9 shows the production curve for castings during the period 1978-1987 in the five product fields, as well as the production curves of the application of the 101 technologies, and the total consumption of castings produced with counter-pressure. The analysis of the data shows that the technologies which realize most fully the advantages of the method were used after 1982 to produce on the average 40% annually (Figure 10) from all castings made with gas counter-pressure in the Metals Technology Company. This means that the results from the analysis of these technologies can be applied with a high degree of reliability to the counter-pressure casting technology as a whole.

A special unit was created at the company for studying the penetration of the CPC technologies in the different product fields. The studies of this unit serve to strengthen the links between the market, the institutes for fundamental and applied research, and the production factories. It observes both the behavior of the products produced with CPC technology and the behavior of the competitive technologies.

One of the product niches which was studied recently is the market for heavy truck wheels. Traditionally, this market is dominated by steel wheels. The main tendency, however, is to seek lighter wheels by using deformable aluminum alloys instead of steel. In the case of aluminum wheels, the shape is obtained through plastic deformation.

The opportunities offered by the CPC technology, i.e. that it allows reaching the properties of the products produced with

plastic deformation but at lower costs, make this technology attractive for both producers and consumers of wheels for heavy trucks and buses.

Market studies show that the wheel produced with counter-pressure is a casting which realizes to a large extent the advantages of the technology and will compete successfully with the wheels made with other technologies. This leads to the conclusion that the behavior of the CPC technology in this product field will influence strongly the behavior of the technology as a whole in the future.

Analysis of the export of technologies for counter-pressure casting shows that (See table 2) the interests of the consumers (the producers of aluminum castings which in the majority of cases fulfil their own needs) were oriented to technologies for products which utilize best the advantages of the counter-pressure method over other technologies. The experience gained with time and the technical development make it possible to develop still more complex technologies.

From 1975 to 1987, the technology was exported in five main product fields:

* parts for agricultural machines,
* parts for heavy engines and reduction gear,
* parts for cars,
* parts for electronics and electro-technology,
* parts for hydro transmissions.

The counter-pressure method has been introduced with the largest number of technologies (42) in the production of parts for heavy engines and reduction gear. It has produced 19 technologies in the production of parts for heavy agricultural machines, and 11 in the production of parts for cars.

2.3. Conclusions about the Development of Product Technologies

The assessment of the product technologies from the point of view of their penetration in the branches and of the realization of the method's advantages leads to several basic conclusions about the fields in which the Metals Technology Company has shaped its product strategy and the possibilities for effective management of its product orientation.

2.3.1. During the period under review, transport machine-building, electronics and electro-technology developed very rapidly. Significant product renovation took place in these subbranches. New types of products were introduced: diesel engines and hydro transmissions, personal computers, professional computers, disk memories, etc., for some of which

Bulgaria is specializing within the frame of CMEA, and for others it is the main supplier for the socialist countries. In order to fulfil the demand for lighter and more technological products, the aluminum castings have been introduced in a great number of new products. The rapid growth in demand for aluminum castings cannot be compensated with a corresponding growth of the casting facilities in the country. The construction and operation of the plant for aluminum castings in a period of shortage of conventional casting facilities laid its mark on the product structure of the plant. In the conditions of centrally balanced production and consumption, the plant and the company with its units for applied research are not able to select the application fields for the CPC technology. These traditional links with consumers are still preserved today. For this reason, a significant part of the technology does not realize the main advantages of counter-pressure casting. This concerns the castings which can be produced with other technologies and do not require constant research after implementation in the institutes of the Metals Technology Company.

2.3.2. In the beginning of the period under review, the Metals Technology Company did not have enough experience and prestige. Therefore, the institutes and factories tried various product fields which did not always realize fully the method's advantages. This is why some studies were made which did not increase the prestige of the method. The development and implementation of a new technology were not always based on careful study of the market and the positions of the potential competitors.

2.3.3. The lack of technological experience and the unproved advantages of the CPC technology as compared with competitive technologies did not allow in the beginning its penetration into the international market and its establishment in potential product niches. The domestic application of the technology makes it impossible for the technology to enter sectors which are not traditionally developed in our economy, but could realize the method's advantages well. In order to gain prestige among the large global producers in these sectors, it is necessary to know the market very well and to invest considerable resources in marketing research and in activities involving risk.

2.3.4. The analysis of the product structure of aluminum castings and of the concrete product technologies makes it possible to reveal the reasons for some cases of reduced competitiveness of the CPC technologies having led to loss of market positions.

CONCLUSION

During the first stage of the study, "Management and Technology Life Cycle," the main regularities in the development of the CPC technology as a product produced and offered by the Metals Technology Company were defined. It became clear that the technology development follows in general the regularities of the product life cycle.

During the second stage of the study, on the basis of analysis of the product structure of the aluminum castings, the following results were obtained:

1. The product fields in which the CPC technology had been introduced were defined.

2. The degree of penetration of the technology in product fields in which it has strong competitors was defined.

3. Six product fields were identified in which the CPC technologies have not sufficiently strong competitors at present. The study of the life cycles of some products in these fields and of the factors which affect them will facilitate the task to construct the life cycle of the technology as a product producing an unlimited number of other products. A similar methodological approach allows he solution of the task to create the company's product strategy.

4. The development of new product fields where the CPC technology could be applied may bring changes in the product range. This must be reflected in the input data in the process of development of the company's product strategy.

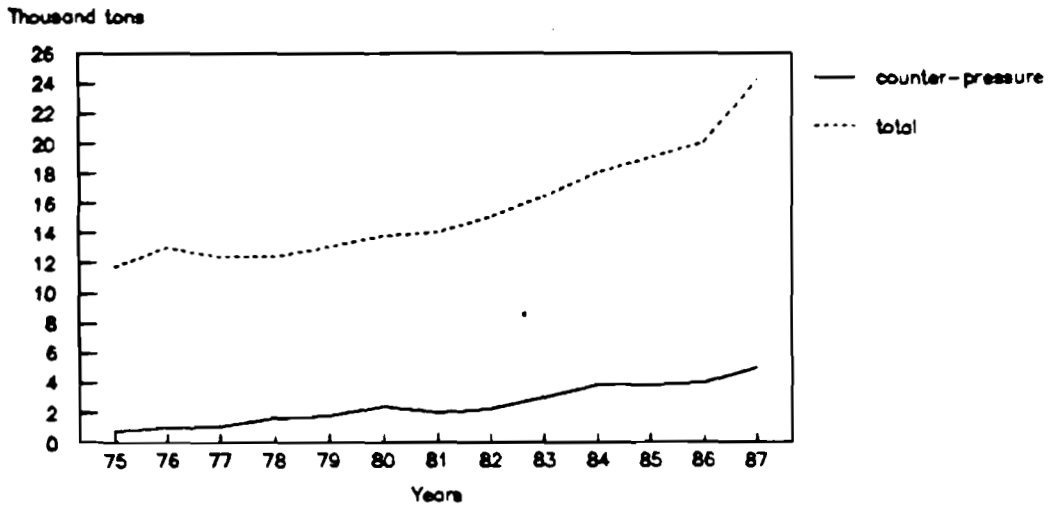

Figure 1: Production Volume of Aluminum Castings (in Bulgaria)

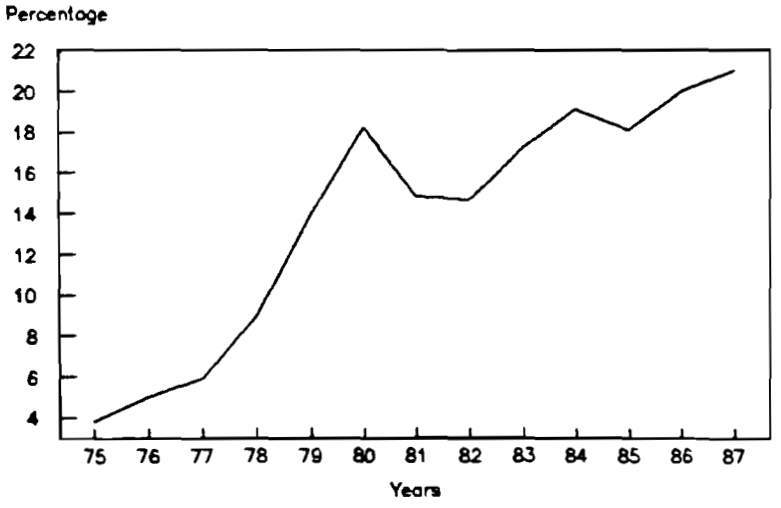

Figure 2: Production Share of Aluminum Castings Produced with Counter-pressure, out of Total Volume of Castings

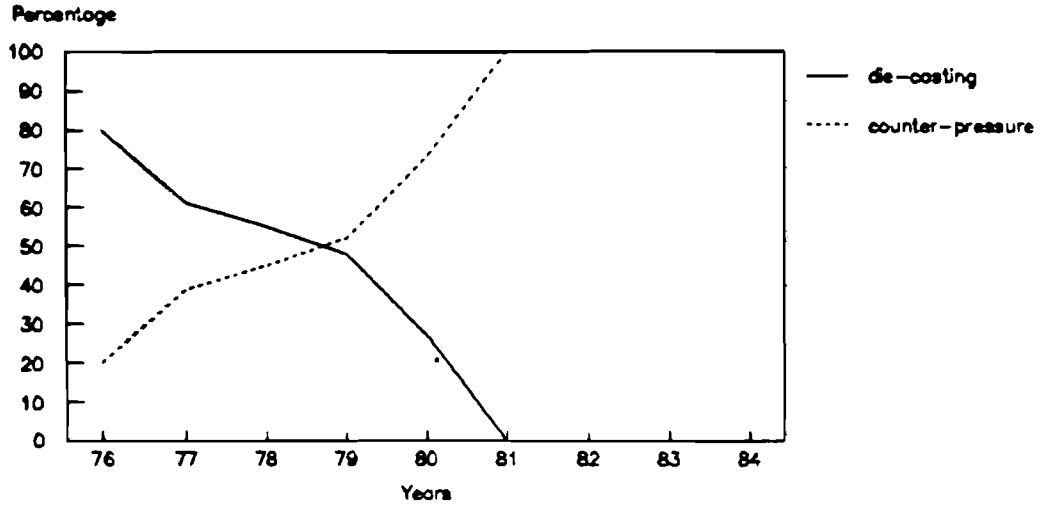

Figure 3: Market Share of Castings for Crank Cases for Diesel Engines, Produced with Different Technologies

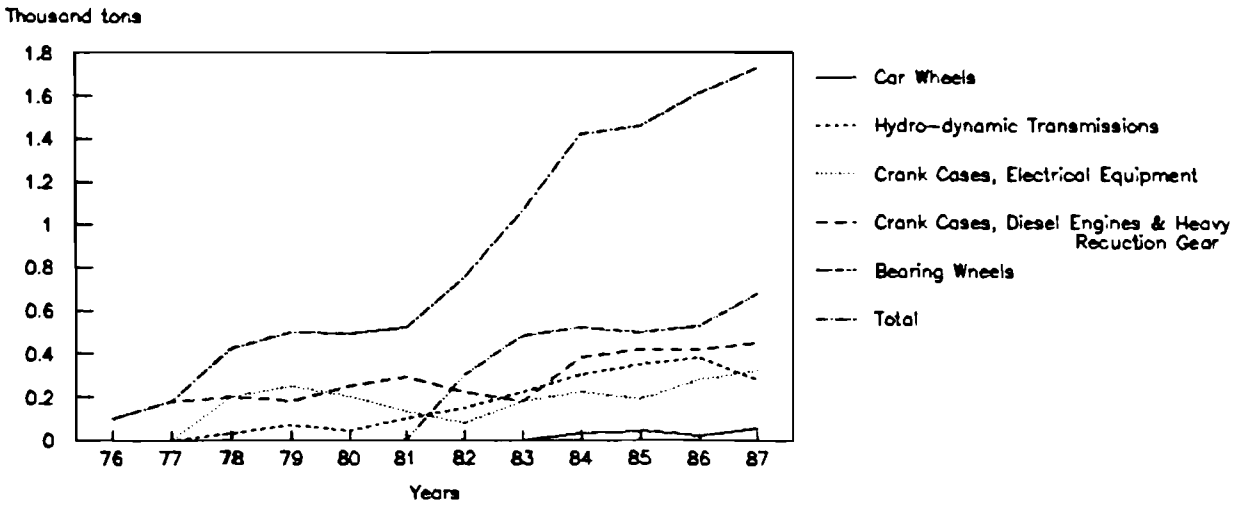

Figure 4: Production Volume of Aluminum Castings in Some Product Fields

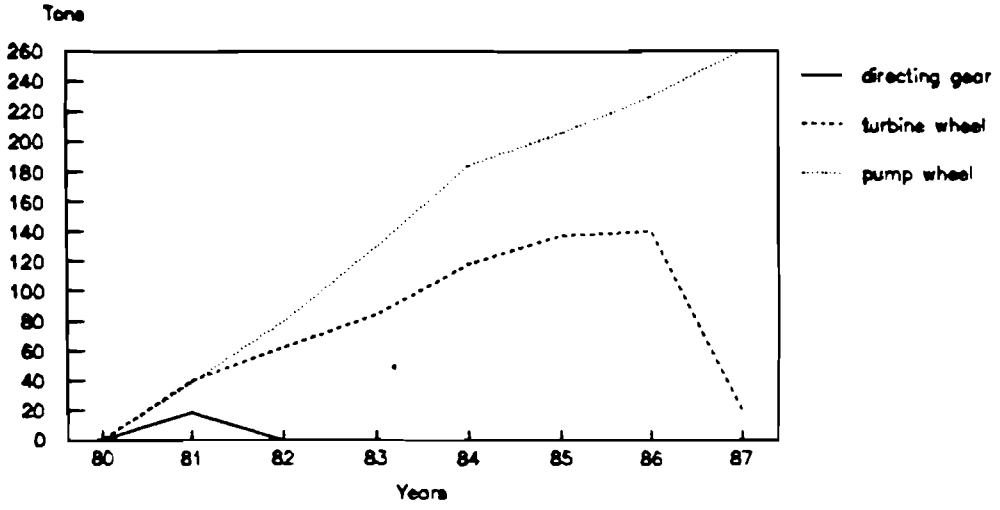

Figure 5: Production of Castings for Hydro Transmissions

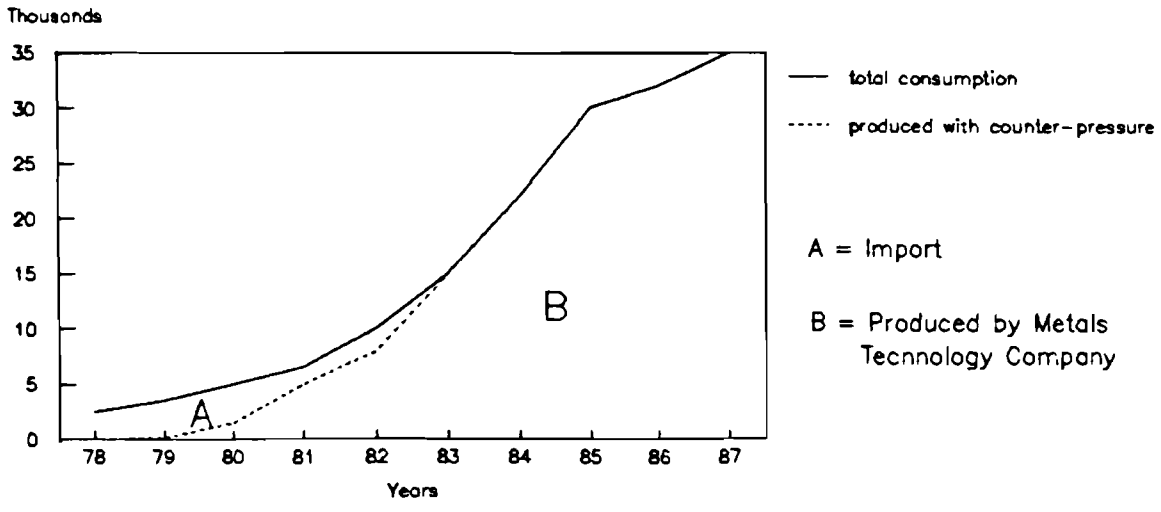

Figure 6: Consumption of Aluminum Castings for Pump Wheels

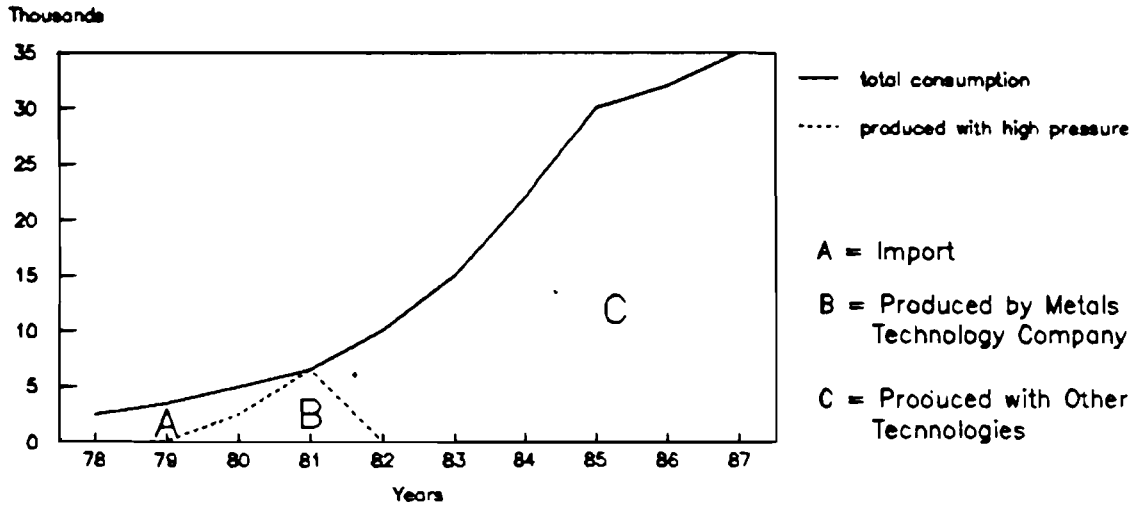

Figure 7: Consumption of Aluminum Castings for Directing Gear

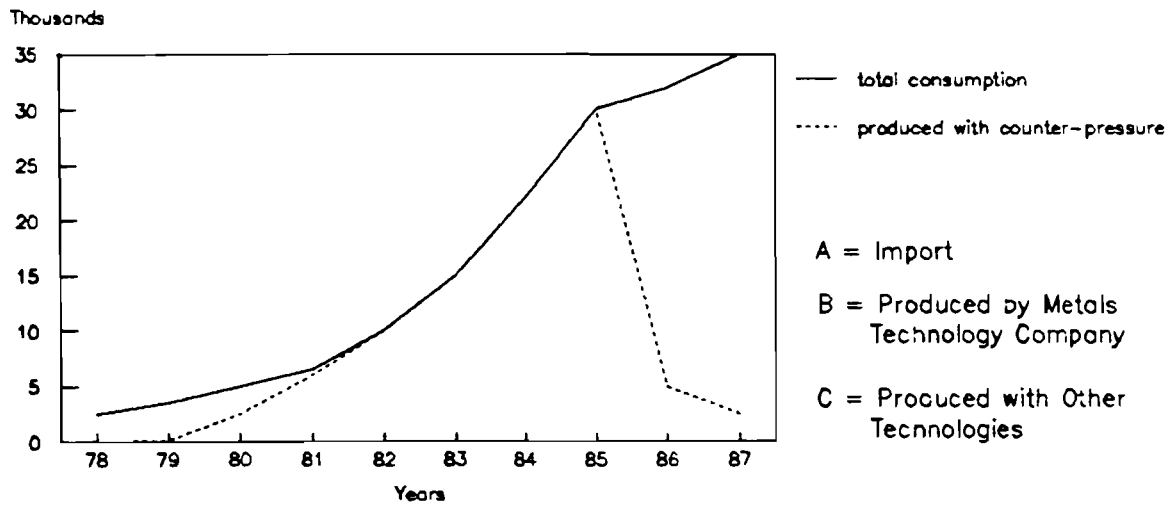

Figure 8: Consumption of Aluminum Castings for Turbine Wheels

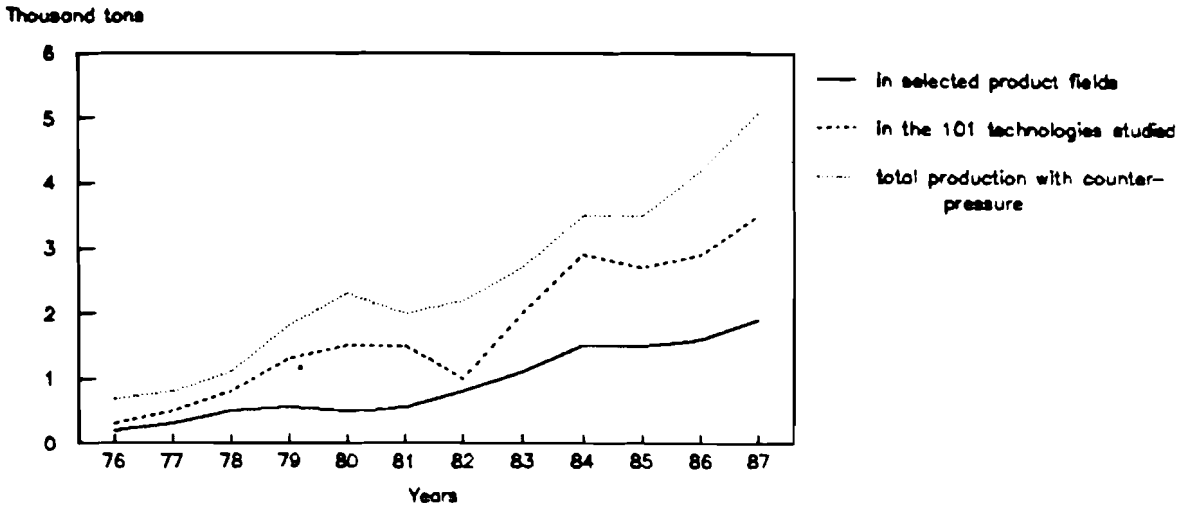

Figure 9: Production Volume of Aluminum Castings

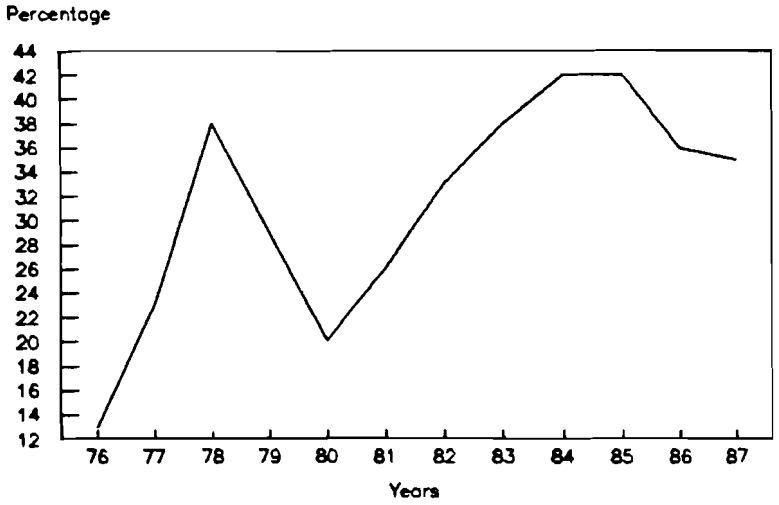

Figure 10: Share of the Castings Produced in the Selected Product Fields out of the Total Volume of Castings Produced with Counter-pressure

TABLE 1: PRODUCTION OF ALUMINUM CASTINGS IN MAIN PRODUCT FIELDS

PRODUCT FIELDS	PRODUCTION VOLUMES IN KIND (TONS)											TOTAL FOR PERIOD (TONS)	NUMBER OF INNOVATIONS
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986		
Transport Machine-building	89.7	108.4	113.7	363.5	600.1	676.3	497.8	1251.0	1412.2	1358.2	1402.2	7873.1	42
Electronics and Electro-technology	163.0	178.0	607.7	821.0	703.0	546.5	295.5	512.7	1005.4	887.5	960.1	6680.4	30
General Machine-building	58.7	116.2	75.6	83.0	213.2	282.2	140.9	287.5	514.9	523.0	576.3	2871.5	29
Total Production in Kind	311.4	402.6	796.0	126.5	1516.3	1505.3	934.2	2051.2	2932.5	2768.7	2938.6	16283.3	101

TABLE 2: VOLUME OF EXPORTS OF TECHNOLOGIES FOR COUNTER-PRESSURE CASTING OF ALUMINUM ALLOYS (NUMBERS)

PRODUCT FIELD	YEARS													TOTAL
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	
1. Agricultural Machine-building					5		2				6	1	5	19
2. Heavy Engines & Reduction Gear	5	6	11			2	8	1			2	9		44
3. Electronics & Electro-technology				6		1	2	1						10
4. Hydro Transmissions									3		4	1		8
5. Car-building				1			2			9	6	1		19