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ADVANCED MATERIALS IN VENEZUELA*

Prepared by

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INTRODUCTION

The materials and engineering sciences permit or enhance the development of other areas of scientific and technological knowledge in fields such as telecommunications, electronics, biotechnology, aeronautics, etc. Progress in these fields depends essentially on the availability of advanced materials of required properties. This situation has oriented investigative activities toward the development of new materials. Consequently, it is important for developing countries to realize the necessity of research work in this direction.

The present work analyzes the national situation in the areas of materials more specifically in the polymers, ceramics and metals fields. The constraints and barriers affecting the development of these fields are also discussed. Finally, a proposal of implementation for the development of new materials in Venezuela is given.

1. CURRENT SITUATION OF VENEZUELA IN THE AREA OF MATERIALS

1.1. Polymers

The petrochemical activities in the area of polymers started in Venezuela 17 years ago with private investors using foreign technology and imported raw materials for the development of down stream activities (manufacturing). Several years later, plants devoted to polymer synthesis (Polystyrene, Polyethylene of low and high density and polyvinyl chloride (PVC)) were built, also using foreign technology but with private and government participation. With the exception of the polysthyrene plant that uses imported raw materials (monomer), all the plants use natural gas from the region (steam craker). The nominal capacity of production for the four plants is shown in Table 1.

The future plans in this area are to expand the already existing plants and to build two new ones: one for the production of polypropylene, with a capacity of 70 thousand metric tons annually (operation to begin in 1991), and the other one for the synthesis of lineal polyethylene of low density with a production capacity of 150 thousand metric tons annually. This last plant is in the development stage of basic engineering and of looking for financial assistance. The new projected values for the working plants are shown in Table 2.

These expansion plans place Venezuela, together with Brazil, as one of the countries with major activities in construction of plants and with high production capacity. Venezuela is expected to increase its production capacity from 200 thousand metric tons (1985) to a total of 637 thousand metric tons per year, by the end of 1992. This gives an increase of 319% in capacity. Presently, Venezuela ocupies fourth place in Latin America with 7% of installed capacity following Argentina (17%), Mexico (24%) and Brazil (47%).

During the 1990s, new technologies and applications are expected to be developed in the following areas: (1) Mixed polymers, (2) Membrane technology, (3) Liquid crystal and (4) Polymer composites.

In Venezuela, the mixed polymer or alloy field has been characterized by a complete separation between what has been done in the investigative sector (Universities and R&D Centers), and what is required in the industrial sector. The latter is lacking an empirical criteria for the form and uses of mixture and alloys to be utilized.

The R&D activities (industrial level) in the plastic and petrochemical areas became necessary for the companies dedicated to thermoplastic resin production, to replace the technological back-up received from the foreign contractors through technical assistance contracts. Since the creation of joint companies, in this case Estireno del Zulia, the contract established a minimum reserve of 1% to be dedicated to R&D activities. Because of the successful results achieved, it was decided to form a new company (INDESCA) dedicated only to R&D activities, and also to give technical assistance services to the buyers of resin. INDESCA created a joint venture program with several companies producing various types of resin (Polyethylene of low and high density, polyvinyl chloride, etc.). INDESCA dedicated a total of 226 thousand man-hours between the years 1983-1987 (see Fig. 1 in the annual average percentage) to R&D activities.

The data related to INDESCA's R&D activities is presented in Table 3. This data gives an increase rate of 12% in R&D activities. All of this has placed INDESCA as one of the principal R&D centers for the petrochemical and thermoplastic industries. A summary of its activities up to 1988 is also given in Table 4.

In 1982, another Venezuelan research center (INTEVEP) developed a petrochemical unit. This group was created with the purpose of giving technical, process simulation, catalyst and chemical analytical assistance to the petrochemical industry. Since its creation, the unit has guided its R&D activities towards the polymer area in projects such as:

mixed polymers, polymer composition, polymer membrane, polymers for engineering applications, recycling of polymers, characterization of natural polymers and physical properties and ziegler-nata synthesis.

The R&D activities, at the university level, have been concentrated mainly in four universities (UCV, UDO, ULA and USB), with groups of investigators that have activities and objectives clearly defined.

The UCV group (Universidad Central de Venezuela) associated with the School of Chemistry in the Science Department is dedicated to the chemistry of polymers. This covers polymerization reactions, polymer synthesis to develop a catalyst for the polyolefin synthesis from titanium, zirconium and hafnium minerals and chromatography techniques for the separation of components by size and molecular weight.

The UDO (Universidad de Oriente) group is associated with the Physics Department, and it is dedicated to electrical studies of polymer materials by thermally stimulated current technique. The main objective of this group is to develop new materials with strategic applications: for example, piezoelectrics, pyroelectrics and electro-photoconductor polymers.

The ULA (Universidad de los Andes) group is working in polymer synthesis, specifically, in the development of specific catalysts for the production of polyamines and also in the development of biopolymers for the pharmaceutical and biomedical industries.

The USB (Universidad Simón Bolívar) research group is divided among two departments: Materials Science and Mechanical Engineering. The first one is working on the physical properties of polymers while the second one has two principal areas of investigation: Polymer transformation and Rheology. Currently, both departments are concentrating all their efforts in the following subjects: traditionally mixed polymers, studies on the reological, mechanical and thermical properties of polymers, nucleation of polymers, studies of polymers of control rheology, studies on the flow of polymeric solutions through porous beds and elongated flows (joint project with the University of Bristol, England), simulation of transformation process by finite-element and finite-difference methods, and crystallization process of polycarbonates. Future investigation developments are in the areas of: physical mixture of polyethylene of low density and polyproylene with of the purpose of producing tough materials from national raw materials, rheological and physical properties of polymeric crystal liquids, and recycling of polymers. Also the USB group gives technical assistance to

INDESCA, INTEVEP and other national manufacturing industries.

As can be seen from the discussion above, it is evident that the polymer area in Venezuela present a very uncommon situation: the existence of a research group with complementary activities, not only at the universities, but also at the R&D industrial centers. This natural capacity to work together should be directed towards a big national project in the development of new materials in the area of polymers.

1.2 Ceramics

The ceramic area was developed to cover the necessities of two main sectors: the steel sector which utilizes in an extensive way refractory materials and the technical ceramic and sanitary sector. This last sector was developed because of the presence of foreign capital and the low energy cost in the country. Presently, the ceramic area in Venezuela is concentrated mainly in traditional applications such as stoneware and restroom fixtures or in the production of basic articles for the operation of other industries (refractory, glass, cement and electrical insulators).

Venezuela has around 200 companies related to the ceramic industry; 25 of then can be considered big companies with an approximate total of 20,000 to 25,000 employees and a gross income of US.$ 300 to 600 million per year. As mentioned previously, all these companies were established in Venezuela taking advantage of the raw materials available in the country, low energy cost, mass consumption or a combination of all these factors. Most of the production is dedicated to satisfy the national market. However, some other areas are competing in the international market.

The development of the national ceramic industry will depend on the exploitation of the non-metals resources available in the country such as:

(1) Exploitation and beneficiation of clays and caolins to obtain homogeneous materials of high quality needed in the traditional ceramic industry.

(2) Exploration and exploitation of zirconium minerals for the refractory and ceramic coating industry. In addition, these minerals are the basis for obtaining zirconium oxide, a material with important applications because of the excellent

mechanical properties which give an increase in toughness to ceramics.

(3) Beneficiation of alumina "metallurgical grade" to obtain alumina "ceramic grade", with important applications in the ceramic, refractory and abrasive industries. The world markert for the alumina "ceramic grade" is estimated to be more than 500 million dollars per year.

The future of the ceramic industry in Venezuela seems to be very promising. The country has important mineral resources that can be exploited commercially with potential applications in high development technologies such as pure silica for the electronic industry, iron oxides for the fabrication of magnets and ferrites that can be used for electrical and electronic applications.

1.3 Metal Alloys

The metallurgical and metalmechanic industries in Venezuela started 50 years ago and went through five stages. It began as an incipient industry based on small foundries and metalmechanic shops, in the initial stage (during the forties). In the next decades, the country received considerable income from the oil exploitation giving rise to a civil construction program with great influence in the metallurgical sector. Sivensa and other companies were created and also studies for the extraction and processing of iron were initiated.

From 1960 to 1970, Venezuela, for the first time, transformed its raw materials by processing iron and reducing imported alumina. The decade of the 70's can be considered the principal era of industrialization because of the enormous financial resources received. The capacity of the steel industry was increased four times and the aluminum industry eight times. At the same time, the oil industry, nationalized by that time, began to purchase equipment and local services favoring the expansion of the metallurgical and metalmechanic sector.

At the begining of 1970, the CVG (Venezuelan Corporation of Guayana) adopted the direct reduction technology to produce steel. This decision was fully justified by the iron mineral resources and electric energy available in the country, and the natural gas reserve used as a reducing gas. At the present moment, Venezuela is the world's leading country in this technology.

In 1983 the steel industry started a new period with the economic integration of private installations and with the initiation of some new projects. However, this new period was affected by several factors: (1) An obsolete installation capacity, (2) Consolidation of the industrial reconversion, (3) Necessity of technical personnel able to adapt and innovate technology and management with the objective of reaching a competitive level in the international market.

The evolution of the apparent metal asset consumption since 1984 is given in Table 5. The production of liquid steel during the same period was increased from 2.8 to 3.4 million of tons to satisfy the high consumption in developing countries, but this level differs greatly from the corresponding level in developed countries.

As a result of the private and public investments in this sector, it can be said that the installed capacity of the steel industry is more than 5 million metric tons per year. However, the production of liquid steel never reached its maximum level in the year 1988. The distribution of these capacities is presented in Table 6. Figure 2 gives a summary of the plants currently in operation. At the present moment, these plants are directing their efforts to increase their production over the installed capacity (Table 6).

Table 7 shows the installation projects for this area which are in different stages of development, Sidor's expansion being the one with major possibilities of success in the short range.

One of the most ambitious project is the COMSIGUA, a CVG-KOBE STEEL joint venture. It is expected to begin operation by 1996 (total production will be exported to Japan) with a capacity of 5 x 10^6 metric tons per year. The general tendency is toward pellet production (7 x 10^6 TM/year) and to install a reduction capacity (3 x 10^6 TM/year).

Another private project of great interest for the technological development of the country is ACEREX, a plant that is expected to install a unit for the production of special alloys.

The R&D activities in the iron and steel sector started with the creation of the following R&D centers: School of Metallurgical Engineering and Science Materials at the Universidad Central de Venezuela (UCV) in 1970, the IVIC Engineering Center (1972), the Institute of Metallurgical Investigation "INMETAL" at USB (1974), the SIDOR's Investigation Center (1974), the Material Science Department at the Universidad Simón Bolívar (USB) (1975), the Material and Ceramic Group of the IUT (1974) and the Fundación Instituto de Ingeniería in 1982. All of these R&D group have been affected by the economic crisis of these last years in the country. However, an installed capacity has been forming in the country. The Sidor's Investigation Center has developed a program in the production, processing and development of plane products such as the AREX process of direct reduction.

At the university level, the UCV has today a physical infrastructure which permits it to characterize and investigate from the agglomeration aspect to the steel processing kinetics.

The Science and Process Department at USB has the laboratory facilities to process iron and carbon minerals and also has the capacity to give technical support to the industrial sector. All this infrastructure can be directed toward a main project to fulfill the steel industry's necessities (a national steel program).

In the developed countries, the industries have guided the investigative activities at the universities and other research centers by giving financial support. This situation has never occurred in Venezuela. Therefore, the national steel industry should coordinate and concentrate its efforts to provide adequate financial support for the R&D activities in this sector.

The national aluminum industry, at this moment, is making a great investment to increase the natural production capacity of primary and secondary aluminum, alumina and the exploitation of bauxite mines. The principal goal is to take the production of primary aluminum up to 200,000 metric tons per year, which will increase the present productivity four times by the end of this century.

The R&D activities in the aluminum area are concentrated in raw materials processing and development of alloys. The characterization of the raw materials is very important to determine the necessary conditions to produce bauxite "metallurgical grade".

In Venezuela, the exploitation of the bauxite for the aluminum products for ALACASA y VENALUM open many possibilities for hydrometallurgical investigation in aluminum production.

In general, most of the investigative activities have been concentrated to optimize the Hall-Héroult process by a mathematical modeling to up-date the information concerning physical-chemical properties and cell behavior. These models have made it possible to establish the design requirements of the cells and to select materials to study the behavior of the process following a simulation process which incorporates the mechanical forces effects and allows the prediction of voltage drop, fluid dynamics, process interference and the evaporation and transport of impurities.

In the next few years, the informatics advances and the development of more precise measuring devices will emphasize the tendency toward computerized processes.

Some work has been done to create an Aluminum Research Center (CITAL) in Venezuela, but it is not a reality yet. This situation indicates a tendency for the aluminum industry to have their own research centers. For example, VENALUM is developing a production line with 300KA cells, an effort that combines a simulation and a wide control process for the design and the construction of a research center to fulfill the necessities of the process.

Another area of investigation in Venezuela in the aluminum sector is associated with the development and optimization of aluminum alloys. This is one of the most prominent areas from the economic point of view. Until now, the adopted strategy is to make the country one of the major primary aluminum producers with the purpose of having a better negotiation capacity and production manipulation. This goal leads to the development of a processing and manufacturing industry with a capacity to produce special aluminum alloys and with two clearly defined R&D activities. The first one implies a negotiation process for the purchasing, assimilation and development of products and new process technologies. The second one is oriented toward the monitoring of advanced technologies in the sector. This point raises the necessity for an effective link between the R&D centers and the national aluminum industry. However, at the present, most of the R&D activities have individual and isolated characters. The projects are developed with academic goals and in a few cases with national or foreign financial support.

Finally it can be said that the country has the fundamental academic orientation (at the universities and research institutes), resources and sufficient experience to develop a national technological capacity for the assimilation of new process and product technologies.

2. CONSTRAINTS AND BARRIERS TO THE DEVELOPMENT OF ADVANCED MATERIALS IN VENEZUELA

In order to implement a national policy for investigation and development in the areas of engineering and materials science several factors have to be considered: (1) human resources and physical infrastructure evaluation, (2) the Venezuelan industry's opportunities for technological applications associated with the production of new materials, (3) the industry's response to technologies in the new materials area and (4) the raw materials access and the role of other factors that can lead to developing competitive advantages.

2.1 Human resources and physical infrastructure evaluation

Figure 3 gives a summary of the current personnel resources available (in the plants) in areas of polymers, ceramics, metals and alloys and new materials. This figure gives the results of approximately 88 scientists in the field of new materials, 31 in metals and alloys, 7 in ceramics and 22 in the polymer field. The educational levels corresponding to each one of the analyzed categories are presented in Figure 4.

As can be seen, from a total of 70 PhDs, only 52 are dedicated to the new materials area. Therefore, it is evident that the country does not have sufficient human resources to cover a national science program on new materials. A similar conclusion can be obtained by analyzing the numbers of auxiliary personnel dedicated to R&D activities such as master level researchers, engineers and technicians. From all of this the necessity of an extensive educational formation program in the area of new materials is evident.

Figure 5 presents the R&D human resources required in the national science program. The human capacity in the area of new materials is expected to increase considerably in the next five years. This gives a different perspective since it would have a mobilized sector and the promise of valuable resources to reactivate the R&D activities. However, it will also demand a great effort to update the lab equipment infrastructure and to create a strong support program for continuous research work.

It is important to point out another aspect of the R&D activities which is related to the local lack of integration between the basic and applied research work at the universities, and the experimental development and productive technologies demanded by the national industries. This situation is a direct consequence of the absence of investigative activities in the industries, a basic requirement to establish a permanent bond and increase technological development and complexity. Furthermore, the presence of different objectives, a different space or locus and the lack of knowledge of the needs of one and of the capacity of the other, diverse financial mechanisms of control and finally different social aspects related to one or another activity make more difficult the relationship between R&D centers and the industrial sector.

If these negative tendencies associated with a total lack of integration are not corrected, the results will be: (1) the universities will continue to do research in process and product but without reaching a satisfactory level of development, an adequate transfer mechanism and the correct prices so the industries can take the final stage in the production of new development of advanced materials, (2) most of the industries will continue to make adaptations and modifications in product and process with the idea of learning by doing it, and with low scientific and technological effect, (3) the link between industries, universities and R&D centers will remain in terms of specialized services or small consulting services oriented, in most cases, toward informal levels.

2.2 Potential applications in the national industries and the domain of production technologies

New materials are related to specific uses in high technology industries where operating services demand extreme conditions in material behaviors. We are referring to applications in the electronic, telecommunication and aeronautic fields. In these areas, the scientific and technological component requirements are very high; consequently, the equipment and identification infrastructure is very sophisticated with an extremely high cost. Furthermore, the knowledge transfer structure from the lab to the production unit should be flexible. The key to the process is the transfer velocity and this implies explicit mechanism of connection and clear ways of communication between investigators and innovating manufacturers. Unfortunately, this level is beyond the current situation of our country.

In other words, we can see the material sector in a dynamic tension between two tendencies. On one side we have the traditional industry efforts to optimize and capitalize on the already existing technological infrastructure to reduce cost and to become competitive with the new advances. But on the other side, we have the new materials pressure to develop new processes and to create new technologies that would improve on the conventional ones. The result of these two tendencies is a compromise between incremental innovations and those with a sharp break with the past.

The metal sector has survived and it will continue to survive for several years because of the influence of incremental innovations. Venezuela does not have the capacity to develop innovated alloys or to implant advanced processes such as flash solidification. Therefore, future plans are to improve the existing technologies in steel and aluminum alloys processing. This situation along with an assimilation program and the adaptation of local conditions to a learning process will lead to the development of an innovated culture in the metal sector. This new learning skill will permit the creation of a nuclear group of investigators in conjunction with universities and R&D centers for the monitoring and eventual development of more sophisticated technologies.

The ceramic and polymer sector present different levels of technological capacities. As already discussed, the national ceramic industry is dedicated to the production of conventional products and until now has not produced any kind of advanced ceramics. However, the future of this sector is very promising and with the current increased capacity of R&D activities through the universities, it seems that a well-defined state policy will permit the initiation of a technological learning process in advanced ceramic processing.

The polymer situation is also very favorable. The petroleum and petrochemical industries not only have developed their own investigative capacity, but also have stimulated their technical competitive networks with national and foreign companies, universities and R&D centers. In addition, the possibilities of developing new materials in the polymer area are very extensive. Mixed polymers, thermoplastic and reinforced thermostable materials can be fused in an ambitious program to develop new products, patents and possibilities of being associated with foreign groups for the transference or purchasing of new technologies.

3. PROPOSAL FOR IMPLEMENTATION FOR THE DEVELOPMENT OF NEW MATERIALS IN VENEZUELA

Venezuela has very prominent opportunities to become part of the new materials venture. The mineral resources available in the country, the low energy cost, the government support through the program of industrial reconversion and the reactivation of the R&D capacities and physical infrastructure in the nation, place Venezuela in a leading position in Latin America in the development of new materials. This position can be reached through the activation of a national research center with R&D activities in the engineering and material science fields. This national research center should accomplish three main activities:

(1) Development of a diagnostic unit for marketing
(2) Development of an instrumentation capacity, and
(3) Development of the capacity to offer technological services

With the diagnostic unit, the national research center will fulfill the necessities to promote the development of systematic programs. It will create a permanent link between the investigative activities and the advances in these areas. It will also increase productivity and the development of the national industry's technical capacity in the area of new materials. The work should not only be directed toward identification of industry requirements, but also toward the creation of very attractive offers, that will make possible the association of the national industries with the development of new materials.

A new concept of technological services should be redefined in order to attract the small and big companies in the new materials venture. This places the national research center with two main strategies to achieve. The first one is to transfer its knowledge skills and its technological capacities to the industries with the purpose of solving problems of quality associated with processing failures; the second one is to center its attention on the selection of a special program (i.e. a program with technical complexity). The performance of this program will give a clear demostration of the technological capacity reached by this center. Table 8 gives some suggestions. In this table the areas of processing materials in the fields of metals, polymers and ceramics are defined.

Finally, we considered it necessary to emphasize the significance of research and development at the process level. Until now, this activity has been ignored by the industrial and academic sectors; but without it, there is not optimization and no increase in competitiveness with regard to conventional technologies. Much less will there be solutions to the difficult problems that must be resolved before the new technology can become reality; since processing research is the natural link between the academic and the industrial.

4. CONCLUSIONS AND RECOMMENDATIONS

Venezuela has very prominent opportunities to become part of the new materials venture. The mineral resources available in the country, the low energy cost, the government support through the program of industrial reconversion and the reactivation of the R&D capacities and physical infrastructure in the nation, place Venezuela in a leading position in Latin America in the development of new materials.

The review of the national situation in the material science field has revealed a very active sector, with many opportunities for research and development of different disciplines and technological innovations. These characteristics give the new materials area an appreciable socio-ecomomic impact on the different national sectors, which implies the creation of a wide market for the new products with applications to different industrial sectors (microelectronic, information science, bioengineering, etc).

Many opportunities were found for the reactivation of the investigative capacity and development of the new materials technologies to the national level. For this, it is necessary to take into consideration the following suggestions:

(1) Harmonize the programs for human resources formation with parallel efforts in the development of the national investigative infrastructure.

(2) Facilitate the financing of the diagnosis of the real conditions of the national industries as an important stage for policy definitions to stimulate increased technological capacities of the companies in this sector.

(3) Implementation of financial programs to stimulate the use of R&D services and also to stimulate the internal investigative capacities of the manufacturers in the new materials area.

(4) Implementation of specific research programs in the area of materials processing and in the development of measuring equipment for process control. It will be very helpful to combine the purchase of sophisticated measuring devices with a program for the development of instruments compatible with the present technology of the country.

(5) Stimulate the development of a national technological network and its integration with Latin American, North American, European and Asian networks with common objectives. This network should be formed by the industrial and the investigative sectors and will act as an organism to design international cooperative programs oriented to the execution of projects of technological innovation as functions of the specific requirements of the national materials industry.

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6. FIGURES AND TABLES

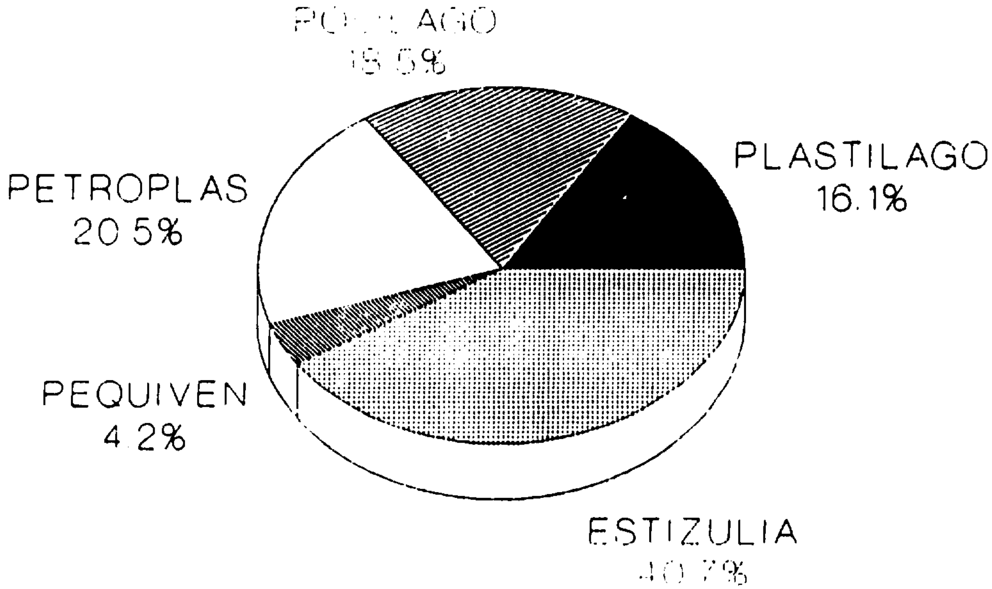

Figure 1. Annual average percentage of man-hour dedicated to projects by INDESCA (1983-1987).

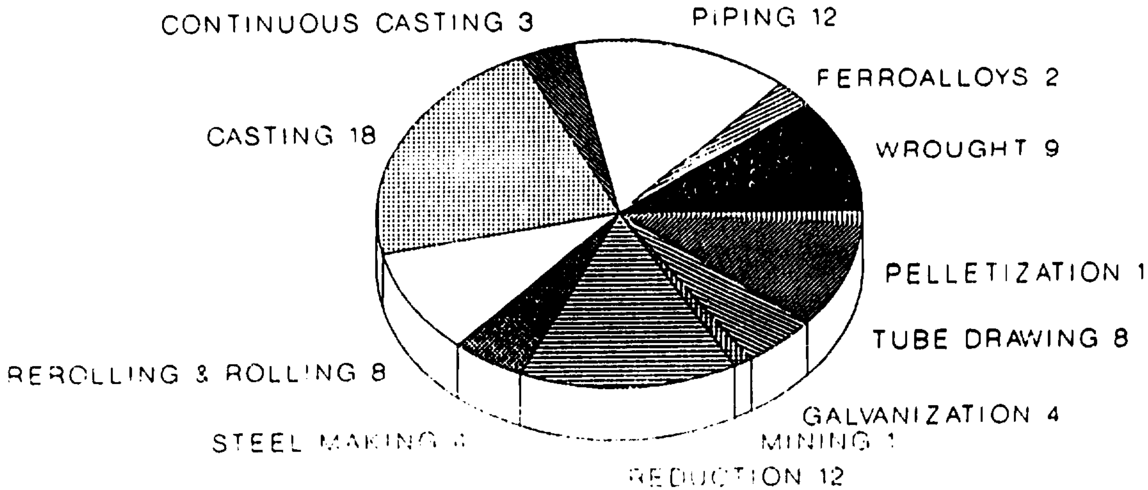

Figure 2. Summary of the plants currently in operation.

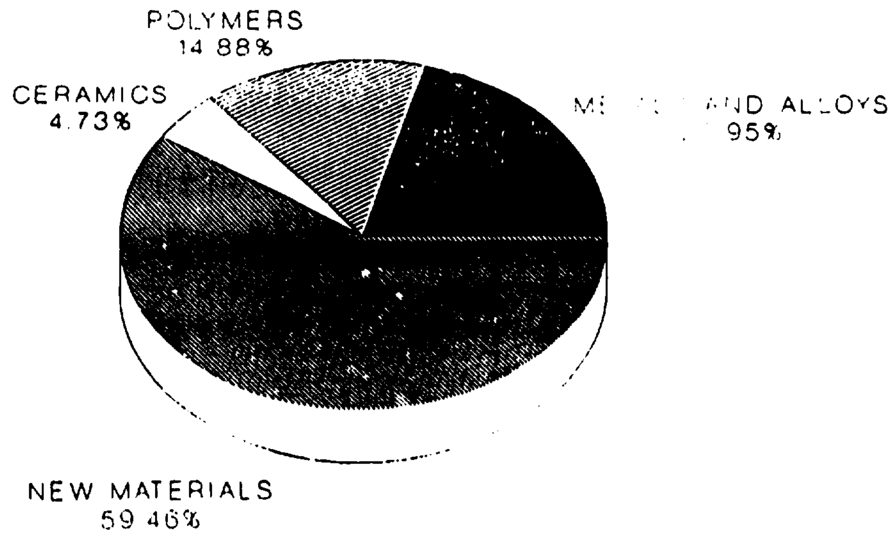

Figure 3. Current personnel resources available (in the Plants) in areas of polymers, ceramics, metals and new materials.

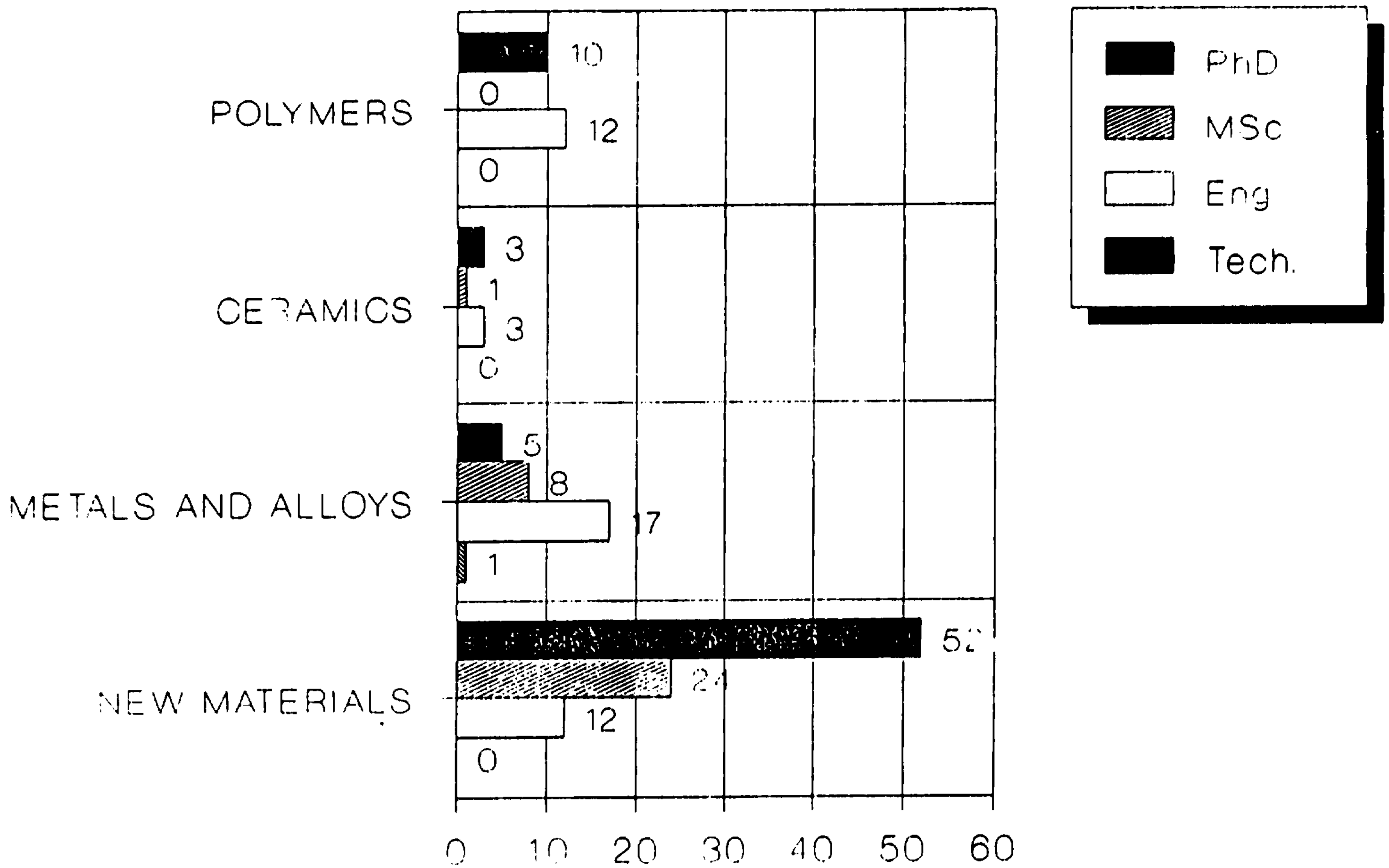

Figure 4. Plant personnel in the new materials area.

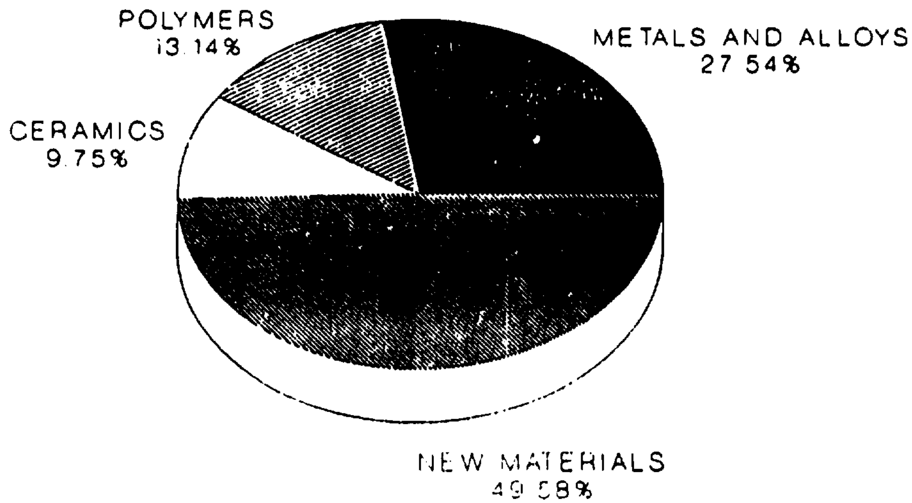

Figure 5. Demand for human resources by speciality.

Table 1.- Production capacity of thermoplastics in Venezuela.

Product	Nominal Capacity	Starts	Owner
Polystyrene	40	1973	ESTIZULIA
Polyethylene of low density	60	1976	POLILAGO
Polyvinyl chloride	40	1980	PETROPLAS
Polyethylene of high density	60	1983	PLASTILAGO
TOTAL	200		

TABLE 2. Expansion production capacity.

Product	Increment capacity (x 10^{-3} MT/year)
Polyethylene of low density	60
Polyethylene of high density	20
Polystyrene	7
Polyvinyl chloride	80

Source: PEQUIVEN

TABLE 3. Operation projection of INDESCA (1989-1993).

ASPECT	1989	1990	1991	1992	1993
Man-Hours (x 1000)	88	98	113	127	142
Operational Staff	66	76	86	96	106
Technical and Administrative Staff	44	46	46	48	50
TOTAL PERSONNEL	110	122	132	144	156

TABLE 4. Description of Operational Departments

Applications Department
* Technical services * Consulting services * Development of new applications for conventional products * Development of products through mechanic mixture with polymers, charge and additives * Investigation of new transformation equipment and applications * Evaluation of processability and thermomechanical properties of products * Computer simulation of transformation process
Applied Investigation Departments
* Improvement of products and processes * Computer simulation of process * Evaluation of raw materials properties and characterization of molecular products * Evaluation of quality control system * Expansion of raw materials suppliers * Maintanance, integral protection and technical information center

TABLE 5. Apparent Metallic Asset Consumption

YEAR	M.T. x 10^3
1984	2,778
1985	3,180
1986	3,442
1987	3,875
1988	3,455
1989	3,033

Source: ILAFA "ANUARIO ESTADISTICO" 1989.

TABLE 6. Installed Capacity

COMPANY	PRODUCTION MTX 1000/ YEAR	FURNACES	CONTINUOUS CASTING	ROLLING MILL MTX 1000/YEAR	OTHERS	PRODUCTS
SIDETUR						
Caracas	190	Electric				Rebar, Bar Platen
Barquisimeto	287	Electric	yes	250		Channel IPN, UPN
Guarenas				80		Bar, Platen Channel
Guayana	600 (MIDREX) 320			40		
SIZUCA (Ciudad Ojeda)	40.1	Electric	yes	35.5		Smooth Bar Square Bar
CABITACA (Táchira)				20		Smooth Rebar, Crossbows, Rectangles, Squares
PERFILSA (Barquisimeto)				22		Crossbow, Channels
IVEFA (Tinaquillo)	25	Electric	yes	20	Forge and Three-Edges	Round Bar, Forging Cylinders, Rings, Valves, Plunge
ACEREX (Barcelona)	10	Electric			Forge, 2nd. Metals	Bars, Special forms (Technical Quality)
HEVENSA (Guayana)	30	Electric				Ferromanganese, Ferrosilicon, Silico-manganese
FESILVEN	50	Electric				Ferrosilicon
SIDETRUCA (Trujillo)	50	Electric	yes	50		Special Steels, Round Bar and Square Bar
FORDOCA (Barcelona)	10	Electric			Forge and Foundry	Powdering Mill Cylinder Bar
F. SANTA CLARA Carabobo)					24 Forger	Forging of Industry, Petroleum and Automotive Parts
SIDOR	700 (HER) 1200 (HER) 2400 (HER) 1550 (MIDREX) 2460 (HYL)	1200 (S.M.) Electric Electric	yes yes	1000 (1100) 500 (800) 100 (500) 750 (300) 2100 (Planes)	110 (Pipes) 450 (Heavy Wire) 6800 (Pellets)	Bloom plate, palanquin, Channel, Rebar, Platen, Bands, Laminate, Pipes, thin Plates
FIOR	400 (Fior)					HDR
OPCO	750 (MIDREX)					HDR, Plant, Midorca

TABLE 7. Projects.

COMPANY	PRODUCTION M.Tx103/year	CONTINUOUS CASTING T.M.x103/year	OTHERS	OBSERVATIONS
COMSIGUA	3,000 (Pellets) 1,000 (MIDREX) 1,000 (HEA)	Yes		KOBE-CVG
CDC	4,000 (Pellets)			Canada, Division Consorce
BRICAR	500 (MIDREX)			CVG - Private
BRIGUA	940 (HYLIII)			CVG - Ferrostal
SIDOR	576 (MIDREX)		335 (tubes)	Expansion Plant Tubes and MIDREX plant
FESILVEN	38.5			Ferroilicon and metallic Si

TABLE 8. Research areas in the field of processing

Metals	Flash solidification. Automatization. recycling. Development of Al and Fe alloys. Development of metals extraction process.
Ceramics	Development of ceramics with electrical, electronic and magnetic applications. Production of ceramic powders (alumina, zirconium and magnesia). Injection molds process. Isostatic press. Development of special refractory materials.
Polymers	Development of mixed polymers Reaction and injection processes. Recycling technologies. Composites materials (high performance fibers).
Optoelectronics	Chemical vapor deposition (CVD). Molecular Beam Epitaxy

Figure 1. Annual average percentage of man-hour dedicated to projects by INDESCA (1983-1987).

Figure 2. Summary of the plants currently in operation.

Figure 3. Current personnel resources available (in the Plants) in areas of polymers, ceramics, metals and new materials.

Figure 4. Plant personnel in the new materials area.

Figure 5. Demand for human resources by speciality.