The Present Situation and Prospects of the Italian Chemical Industry — High Polymer Developments

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THE present situation and prospects of the Italian chemical industry is the subject I shall develop especially from the point of view of its historical, economical and evolutionary basis. I shall avoid all the statistical data of the various chemical productions, since they are reported in many publications.

In this short exposé I shall try to give an idea of how the Italian chemical industry was started, which were its developments in the last decades, what is presently the phase in evolution and especially, the trends of its future developments.

I hope that this outline will be interesting because it should demonstrate how spirit of initiative, hard work and confidence were able to overcome initial conditions that were exceptionally difficult.

The Present Situation and its Origin

Italy was a country that had neither coal available in its territory (excluding very low grade lignites with high cost of production) nor petroleum or metallic ores in any important quantity, with the exception of bauxites and iron pyrites.

It is well known that the primary factors in promotion of the chemical industry are the availability of raw materials and the general technological level. In Italy, the raw materials were very few. We can say that the Italian chemical industry started using air, water, salt and pyrites as raw materials; plants were located initially where power was locally available or where it was possible to use seasonal peaks of hydroelectric power.

This availability of electric energy not only made possible the beginning of certain electrolytical productions, like chlorine, soda, aluminum, but also synthetic ammonia was produced in 1924 from electrolytic hydrogen and methanol in 1928, from synthesis gas. The latter was produced in the first continuous low temperature coal gasification plants in the world using oxygen obtained as a by-product of electrolytic hydrogen production or of nitrogen production by air fractionation. The local availabilities of power became absorbed in more economically rewarding uses as the civil consumption of the same was growing in a country that was in a phase of development. Therefore they were less and less available to the chemical industry.

In a country thickly populated, having a limited tillable surface which was, however, extended to the most difficult and least fertile mountainous zones, it was natural to make the first move in the field of phosphatic fertilizers (needed in soils depleted by thousands of years of cultivation) and of nitrogen fertilizers. The latter field promoted the growth in Italy of the great chemical industry in the decade from 1925 to 1935.

From this first platform, the Italian chemical industry developed toward more complex productions like dyestuffs and pharmaceuticals in the period between the two world wars. In the same period there was also another important development favored by the already existing textile industry based on the use of natural fibers. Rayon was manufactured on a large scale so that Italy became one of the leading exporters of this cellulosic fiber.

In this period, Italy had also made great strides in the production of ammonia, calcium carbide, inorganic and organic acids and calcium cyanamid.

Although the Italian chemical industry grew later than the chemical industries of some other European countries, it developed some original concepts and techniques which in some instances contributed to the further development of the chemical industry in the world. Such contribution is considerably more than it would be predicted with the sole consideration of the limited Italian productions.

As an example we quote the high pressure synthesis processes (ammonia, methanol) developed in Italy and other manufacturing units connected with the same, which caused the construction of several plants outside Italy in Europe, America and Asia.

In the years immediately preceding World War II, the Italian chemical industry had attacked new advanced problems. In those years, hydrocarbon hydrogenation plants were built in Bari and Leghorn using some very heavy Albanian crude oils. Such industry could not yet be defined petrochemical since its main purpose was production of fuels, but already there was a trend to utilize certain byproducts to produce chemicals. Furthermore this was an indication that the Italian industry was aiming at special productions in large tonnages.

In the field of synthetic rubber in Ferrara, a plant was built in 1938 to produce butadiene from alcohol and Buna S. In this plant was the first unit in the world that allowed the separation of substances like butadiene and butylene having the same boiling point by extractive distillation. The construction of a plant to manufacture Buna S starting from calcium carbide was started in Terni, but the war prevented the start-up of operation. These plants were an indication of the level reached by the Italian chemical industry before the beginning of World War II.

This war brought severe destruction and damages that halted the development of the Italian chemical industry.

ments. The process for manufacturing berylium oxide has also been perfected; and large quantities have already been produced, though this substance is not yet widely used in French atomic piles.

A first pilot plant for the production of heavy water is to be put into operation shortly, and will function by extracting deuterium from liquid hydrogen. Trials are also being conducted, using gas from Lacq, with the isotope exchange process.

The French chemical industry has also devoted particular attention to developing structural metals, and a great deal of research on the subject has been carried out.

Considerable quantities of magnesium and aluminium are produced at excellent standards of quality. Studies have been made of berylium and zirconium. Ductile niobium, vanadium, molybdenum and chromium will soon be on the market.

Numerous auxiliary materials for the nuclear industry are prepared with highly satisfactory results: for instance, nuclear calcium for use in uranium metallurgy, or control and safety materials such as cadmium, or the liquid metals used in heat transfer.

Finally, in the treatment of irradiated fuels, France's policy was originally directed towards plutonium production, and a plant for processing enriched uranium was built at the atomic centre of Marcoule. Production is to begin there shortly.

Recently, however, it has been decided to conduct a parallel study of uranium 235, and plans for a uranium hexafluoride gaseous diffusion plant are already well advanced.

Incidentally, there is some prospect that this plant, costing between 50 and 60 billion francs, may be established on a broader basis than that of a purely national undertaking.

All of this makes France one of the most advanced countries of Western Europe as regards atomic projects and achievements.

This lengthy statement, however concentrated it may still be, does at least, I feel, give some faint idea of the specific progress made by the French chemical industry. In 1961, just three years from now, the total turn over figure for the French chemical industry, strictly speaking, will be in the neighbourhood of 800 billion francs and the chemical industry will play an essential part in restoring equilibrium to our import-export balance.

When we consider all of the new products the chemical industry has discovered and manufactured throughout the entire world, within only a century, we are truly amazed by the potentialities of the scientific manipulation of matter. The ceaselessly renewed achievements of this industry would seem to be pushing back its own boundaries almost indefinitely.

But such a rich history of achievements—some of which most impress us, because of their possible effects upon the future of the human race—do they not also impose obligations on all of us as well? Some of these obligations are best fulfilled by Governments. Others, however,—and not the least in importance—must be met by ourselves. These problems can only be solved by a sort of "calculated" wisdom; and by our determination to avoid scattered efforts, which are barren and costly,—and all the more costly, since we are faced with new problems at every moment.

A great experiment is now being attempted in this general direction,—and in our old Europe, recently weakened by two terribly destructive wars. This great experiment is the creation of the European Common Market and it is now coming progressively into operation. The paramount condition for its success is the need—on all sides—to abandon the spirit of domination, which springs from an immoderate desire for power and riches. Men must be made to realize that it is loyalty and justice which are the essential conditions for success, in the harmonious and wise carrying out of this great economic project and program.

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During the first years after the war all activity was directed toward the rebuilding of the productive structure of the whole country. The chemical production dropped in 1945-46 to figures quite below those of 1938.

In the last 10 years the Italian people have shown great energy and capacity for work and have rebuilt their country and their industry, going much further than they were before the war, as indicated by the monetary values shown in Table 1.

In the meantime, in Italy, probably preceding other countries of continental Europe, a deep modification of the old conceptions concerning the raw materials for the chemical industry, had taken place.

Before the war, most of the European chemical industry was based on coal; petroleum was not considered a suitable raw material for chemicals.

However, two new and important factors were added to the picture. The first factor was the availability of new raw materials, the second was olefin chemistry.

During the years after 1947, gas fields were discovered and exploited in Northern Italy. Table 2 shows the production figures from 1948 to 1957.

In addition, the increase in the oil production of the Middle East during the last years, the use of more and more efficient and economical transportation means and, last but not least, the geographical position of Italy has allowed the development of a petroleum industry, which has now an approximate capacity of 30 million tons per year of crude. This has disclosed new possibilities for the chemical industry.

The technique of obtaining chemical products from gaseous or liquid hydrocarbons was mostly developed in America during the war. It was almost unknown in Europe where, on the contrary, years of work were spent to obtain the opposite goal, namely synthetic gasoline instead of using the petroleum hydrocarbons as a raw material for chemical synthesis. The latter conception coupled with rationalization of chemical engineering is rightly considered a major contribution given by America to the development of the chemical industry.

During the years after the war, the conditions for the organization of chemical productions from hydrocarbons developed in Italy. Also, in this instance the Italians showed a considerable energy and initative and this time, too, new contributions to chemical progress were made.

This development extended in two main directions: the chemical derivatives of natural gas, which in Italy is practically pure sulphur-free methane, and the derivatives of olefines obtained from petroleum.

The first development is, from the point of view of quantities, more important; first ammonia was produced followed by methanol, acetylene, hydrocyanic acid and some chlorinated solvents. By 1949 the problem of the most complete possible chemical utilization of methane was studied. The products obtainable from this source and the corresponding processes were reviewed. Not all processes were available and some of the available ones were not suitable for the Italian conditions. It was therefore necessary to create suitable processes.

Pilot plants were erected, and at the end of 1951 the projects of two great factories were ready; their erection was carried out with great speed and energy and production began in 1953. Ever since, the ammonia production in Italy has been increasing: as shown by Table 3.

Other plants, for an additional production of 180,000 metric tons per year are now in an advanced stage of construction. At the same time, the whole methanol production, which was based on coke gasification, was shifted to methane as a raw material: Table 4 shows the increase of methanol production from 1952 to 1957.

The production of hydrocyanic acid, acetylene, chlorinated derivatives and other products was started. Another important production going to be actuated in Italy is a plant on advanced phase of construction, located in the vicinity of a natural gas deposit and having a capacity of 35,000 metric tons per year of synthetic rubber of the butadiene styrene type. The scheme, developed by a government industrial group, was initially based on butadiene derived from acetylene obtained from natural gas by partial combustion.

The residual gas from acetylene production will be converted into ammonia. This scheme was later modified to use acetylene for production of vinyl compounds and, starting from petroleum refinery gases, to produce butadiene. It was a courageous decision to decide to build a GRS plant having a capacity higher than Italian consumption, especially at a time when some revolutionary changes may be in the offing in the field of synthetic rubbers.

Acetylene from natural gas is converted in Italy into polyvinylchloride and into acetaldehyde. These productions will certainly increase in the future.

Today, approximately 12% of the Italian production of natural gas is utilized for chemical purposes. This is the highest percentage of any other country in the world. In the United States, which was able to utilize natural gas for chemical purposes almost 25 years ago, it is only 3% and this in a country where natural gas is not the only national fuel (which is practically the case in Italy), but

TABLE 1

ITALIAN CHEMICAL PRODUCTION

Year	Value in billions of Lira (present value)
1938	414
1948	414
1958	1,160

TABLE 2

ITALIAN PRODUCTION OF NATURAL GAS

Year	Millions of Normal cubic meters	Millions of Standard cubic feet
1948	113	4,210
1949	240	8,950
1950	490	18,300
1951	930	34,700
1952	1,380	51,500
1953	2,200	82,000
1954	2,870	107,000
1955	3,490	130,000
1956	4,300	160,000
1957	4,820	180,000

which is the first producer of crude oil and which has three quarters of the world's coal reserves.

In short, the Italian chemical industry has made a really appreciable effort towards the utmost chemical utilization of natural gas and this was one of its new development courses after the war.

The other course was, as already said, that of the high polymers chemistry and particularly of the olefins, in the first place of ethylene obtained from suitable fractions of liquid hydrocarbons. These productions based on petroleum had already reached a high development in the United States, but in 1949 it was still unknown in continental Europe which had many more important basic problems to face, such as alimentation, transportation, supplies, housing and the like.

Italy was one of the first countries of continental Europe to decide to build up a petrochemical industry in 1949.

The utilization of olefins preceded their production from petroleum sources. The raw materials were at that time obtained by emergency methods: the main raw material, ethylene, was obtained from ethanol. When the olefin production plants in turn were completed, the utilizing plants were ready to absorb their production. This was essential for the economy of such expensive plants and brought about a great advantage for the economy of the whole scheme.

Thus, in 1952 the first part of the program based on 10,000 tons per year of ethylene and of the same quantity of propylene had been carried out. In this way was started the first post-war production of high pressure polyethylene in continental Europe.

All this describes the situation of the Italian chemical industry and gives a glimpse of the problems presented by its development. It includes also the bulk of traditional chemical plants which were rapidly reconstructed after the heavy damages of the war on the basis of their original design. This undertaking received great help from natural gas which had, in the meantime, become available.

In this connection, the Italian ammonia and nitrogen fertilizer production methods deserve special mention, because today about a quarter of the world's nitrogen production is obtained by the Italian processes of Fauser-Montecatini or of Casale. The plants constructed all over the world according to these processes amount to several hundreds and the relevant investment is estimated to be around 1,300 million dollars.

Many Italian processes show the characteristic tendency to economize on electric and thermal energy consumptions.

Due to the fact that many important chemical reactions industrially employed are exothermic, in many cases the heat of reaction has been employed for the production of steam; in the past, not only was heat wasted but consumption of cooling water was required. It is common practice in Italy now to recover one ton of steam per ton of sulphuric acid produced or of 0.85 ton of steam per ton of ammonia produced.

The same ideas were extended also to industrial processes of organic chemistry. To give an example I wish to mention the new plant (which was object of my personal attention) for the production of formaldehyde by complete oxidation of methanol in a once through step and with a 90-92% yield of theoretical.

In this plant, not only did we eliminate the steam consumption needed in old plants, but we achieved a production of 0.4 tons of steam per ton of formaldehyde solution produced. This plant, which has a capacity of 70 tons/day, incorporated the principles of American industrial automation so that it is run by one man only.

In 1952, the production of petrochemical derivatives and of polymers enriched the existing basic situation already described. This new production of organic chemicals was carried out with the methods and in the quantities characteristic of the so called heavy chemical industry.

The first PVC plant outside of Germany was built in Italy in 1936. Its capacity was, initially, 1,200 tons/year; today the total PVC capacity in Italy is 50,000 tons/year; and the methods of production have been improved.

The factors behind the rapid growth of the heavy organic chemical industry are, on one hand, the continuously improving experience in the production of olefins and derivatives, and on the other hand the development of new uses and of new end products.

The capacity of the ethylene production of the Ferrara plant is now being expanded from the initial 10,000 to 40,000 tons/year. Other plants, in the stage of erection or on the drawing board will add another 50,000 tons/year capacity in the near future.

The Future

Before starting to examine the future outlook of the Italian chemical industry I wish to mention rapidly the present situation of the field of "man made fibres".

The production of man made fibres represents the Italian effort to rebuild the industry ruined by the war and also the recent development of fully synthetic fibres. This production is indicated in Table 5. The column which we have indicated for 1958 is based on the production of January of this year multiplied by 12; this cannot give an idea of the current development of such industry, since many new plants are in a stage of advanced construction or have been recently put in operation. There-

TABLE 3

ITALIAN PRODUCTION OF AMMONIA

Year	Metric Tons
1952	237,000
1953	294,000
1954	361,000
1955	424,000
1956	484,000
1957	484,000

TABLE 4

ITALIAN PRODUCTION OF METHANOL

Year	Metric Tons
1952	13,500
1953	14,700
1954	24,400
1955	31,600
1956	32,300
1957	38,600

TABLE 5

ITALIAN PRODUCTION OF MAN MADE TEXTILE FIBRES

	1947	1952	1957	Jan. 1958 x 12
Cellulosie Artificial Fibres				
—Viscose	5,597	75,191	126,334	119,880
—Acetate	69	2,477	7,996	9,058
—Cuproammonia process	48	1,910	2,680	2,988
	5,714	79,578	137,010	131,926
—Casein Fibres	–	893	5,616	5,910
Synthetic Fibres				
—Polyamides	17	1,249	9,027	12,087
—Polyesters	–	–	480	1,090
—Polyvinyl	–	–	977	1,100
	17	1,249	10,484	14,277
Total of Man Made Fibres	5,731	81,720	153,110	152,113

fore the actual production in 1958 may differ substantially from the one indicated in our Table 5.

To foresee the long term future in general is not an easy thing and has been called crystal ball gazing. This is even truer in the chemical field, where new solutions of old problems, new approaches and new discoveries may revolutionize old conceptions and old programs. The evolution of the chemical industry is rapid and what yesterday was the knowledge of a few, or today pioneering work, will tomorrow become acquired practice if it will not be already made obsolete by the rapid march of progress.

Each country's contributions to progress are different and are framed in its own environment, are pushed by its particular needs and are depending on its own stage of evolution.

The Italian chemical industry which was born, lived and is still living under difficult conditions, has nevertheless pioneered in some fields with new original conceptions. This is remarkable considering that any new chemical process developed in the laboratory requires expenditure of notable efforts and of substantial money in order to be transformed in a commercial plant. Certainly the future situation will depend on the progress that is now being made and progress is a consequence of fundamental research in Italy and abroad. The results of today's research will determine the new aspects of the industry in the future.

The results of a research organization depend on many factors, some of which cannot be foreseen. Such organizations now have available modern methods and tools of investigation that are powerful and fast. However, the ownership of modern equipment is not all what is needed because good minds are still essential in order to open new fields of fundamental and practical importance.

While fundamental discoveries are the work of individuals and of special aptitudes, helped by collaborators and provided with adequate means, the development of commercial plants and of the applications are rather the result of collectively organized work.

Besides, in the chemical field several years are required to move from the first laboratory conception to commercial production. This is due to the fact that chemical technology is not yet well defined and presents more variables than the other ones, and to the fact that the theory of mechanical models is, in general, not valid for chemical equipment. As a consequence, it is necessary to go through two or even more stages of pilot plants before achieving the first plant on a commercial scale.

Increasing national and international competition, which shall be speeded up in Europe by the creation of the Common Market, shall induce the chemical industry to take part in a competition for research and progress. The present expenses (ranging from 3 to 5% of the total sales) which are incurred for research by the leading chemical industries, shall be still increased. At the same time, all possible ways to make the research more efficient, shall be endeavored. Profitable results in this field are obtained more or less successfully, but it is certain that their general effect is imposing. No other industry has the dynamism of progress which moves the chemical industry.

The future Italian situation will consist in the development of the present one, promoted above all by the improvements obtained in Italy and, by the acquisition of developments made abroad. No industry, no country can aim at achieving a top position if they do not make a contribution to progress.

Chemical progress, as it has already been said, is based on research. However, research depends from another fundamental prerequisite: education.

In Italy, schools of a technical character like the schools of engineering and in particular, the chemical engineering department of the Polytechnic of Milan differ under certain respects from schools of other countries which, specially in North America, have a marked tendency toward specialization.

Our programs are very wide and we try to give to our students a theoretical background as multilateral as possible. Of course this prevents a thorough specialization in given fields. At the end of our courses chemical engineers have also a good knowledge in mathematics and in mechanical and civil engineering. In addition we offer to our students the possibility to undertake some basic research studies.

However we think that this trend is most suited to train people with aptitude to research work.

The department of chemical engineering of the Polytechnic of Milan has been, for several decades, one of the main sources of technical men for the Italian chemical industry. This is also true of men who gave a contribution to the strictly chemical research in Italy. The research laboratories of the Milan Polytechnic always had help from the Italian chemical industry and in turn have given a good contribution to its development.

Studies made in the field of catalysis and of kinetics of chemical reactions, taking into account the actual operating conditions of industrial plants, bring a better understanding of the mechanism of certain processes. Then fundamental contributions were made to have the best rational solutions in the stage of designing process and operation units for industrial plants.

The kinetic study of the mechanism of catalysis and the study of catalyst structures made at the Milan Polytechnic were conducive to original and rational solutions in the methanol synthesis and in oxosynthesis reactions and also to the economical production of formaldehyde in large size units.

Before the last war, studies on synthetic rubber made at our Polytechnic were conducive to original processes developed in the first Italian factory in this field. There was built the first unit in the world to separate, with physical methods, butadiene from butylene, by extractive distillation.

Finally an important result of research carried out at our Polytechnic with scientific methods were the recent contributions to the production of new macromolecules.

Such contributions were made by the X-ray section which developed high level research in the lattice structure of organic substances and also of complex catalytic systems, by the section of organic synthesis, by the section of kinetics of chemical reactions, by the infrared spectrographic section and by the macromolecular physical chemistry section.

The collaboration of specialists in the various sections helped in obtaining results of a fundamental scientific character, which is a basic prerequisite to the subsequent commercial developments.

The discovery of stereospecific polymers like the isotactic and syndiotactic ones, the identification of their structure, the preparation of highly stereospecific catalysts which allow to obtain at will high yields of polymers with the desired steric structure, the synthesis of high purity isotactic polymers, of stereoblock polymers, of etero-block copolymers and of random copolymers, all this opened enormous possibilities to the chemical industry.

What was the exclusive domain of nature, namely to join the monomeric units in a giant macromolecule with a predetermined steric order and not at random is now possible also to man, who also created types of macromolecular structures not existent in nature.

Man, since prehistoric times has been using, without knowing it, macromolecules having pre-ordered steric structure like clothing materials, aliments, materials of construction, but only now is he able to synthetize them in the laboratories and in industrial plants. Isotactic polymers with a high degree of crystallinity, obtained from alpha-olefins, which are very cheap raw materials derived from petroleum, will supply, in the future, materials of construction having, in the oriented state, tensile strength like that of steel, but with a one eighth of its density.

Textile fibres having some mechanical characteristics better than nylon will be obtained at low cost.

The light weight will make it possible to obtain products with insulating properties like wool and with a very pleasant feel. The low price will allow developments in the future entering the fields of classical materials of construction and the paper industry.

In the field of diolefins, industry in the U.S. has been able to produce 1-4 cis polyisoprene almost identical to natural rubber. We have been the first to produce 1-4 cis polybutadiene at a high degree of purity having the same property of natural rubber to crystallize when stretched.

The lower price of butadiene, its already existing availability and the excellent properties of the polybutadiene as sterically pure as the natural rubber, make polybutadiene, in my opinion, more interesting than polyisoprene.

However, even more interesting in the field of synthetic rubbers are in my opinion, the essentially saturated copolymers C_2-C_3 (ethylene-propylene) because of their good elastic properties, coupled with tensile strength and resistance to aging better than that of natural rubber.

Finally the extension of sterospecific processes to monomers that are not hydrocarbons completes the great revolution that is taking place in the field of macromolecules.

One of the most promising fields in the applications of macromolecules having a sterically regular structure will be that of textile fibres. Also, natural fibres (cellulose, silk) have a sterically regular structure. The new processes of stereospecific polymerization consent to obtain macromolecules starting also from highly asimmetric monomers. It is therefore possible to make fibres with high tensile strength and a high melting point starting from olefinic monomers, some of which are available at low cost. The technology of obtaining thin threads has now reached a high level stage of development, but owing to one reason or another the threadable materials are still defective in quality or high in price and man made fibres are still today only 10% of total fibre consumption. Cotton is still the king of fibres in volume of consumption. However the stereospecific catalysis will supply raw materials suitable to obtain fibres suited to various uses at a low price and this may be considered a revolutionary trend.

Going back to the whole field of the Italian chemical productions their quantitative growth will more and more promote the exports especially toward the underdeveloped areas of the world and already the exports take one third of the whole production. It is to be foreseen that the productions based on coal will remain stationary and some will decline. The electrochemical industries have a trend to limit themselves to the most traditional fields like chloro-soda and aluminum.

Another indication of the progress that takes place in technology and in industrial organization is given by the continuous lowering tendency (with some oscillation) of chemical prices, while the expenses for research, technical services, personnel and tax load are increasing. This trend may be noticed all over the world, but is particularly strong in Italy. The selling prices of basic products like synthetic fertilizers and home plastic materials are, in Italy, the lowest in the world. However this situation requires care and the continuous bringing up-to-date of methods, especially considering that the Italian productions are quantitatively modest in comparison with those of other countries, and cannot have the economical advantage of very large production units.

I have indicated some directions of the chemical progress for the next years and the Italian chemical industry will proceed along these paths with the advance due to the priority of its studies and inventions, and with the energy and initative which has been demonstrated in difficult and serious conditions.

Progress that may take place abroad will also help and will be taken into consideration and all considered we shall witness changes and benefits much greater than those brought by violent upheavals and fights among nations.

The beneficial effect of the increasing importance of the chemical industry on every aspect of human activity all over the world will be the best reward of the labors and efforts of the scientists and engineers working in this interesting field.

One of the most revoltuionary changes will be caused, as already said, by the development of processes that will build macromolecules having a predetermined structure. They will render some branches of industry independent from agriculture (in the fields of textiles of paper and of materials of construction) and make more agricultural surfaces available to production of food and feed. In a few decades this will be a strong necessity dictated by the impressive growth of world population and by the increase of the standard of living which is the aim of all countries of this planet where the beginning of peeping in the outer space cannot distract us from our earthly problems. ★ ★ ★